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FIELD INVESTIGATION OF SHIPBOARD/SHORESIDE SEWAGE TRANSFER SYSTEMS AT THE SAN DIEGO NAVAL STATION

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FIELD INVESTIGATION OF SHIPBOARD/SHORESIDE SEWAGE TRANSFER SYSTEMS AT THE SAN DIEGO NAVAL STATION

by

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EXECUTIVE SUMMARY

Field tests of the Navy's ship-to-shore sewage transfer system were conducted at the San Diego Naval Station during 1977. Field tests of installed shipboard Collection, Holding and Transfer (CHT) systems were conducted aboard primarily destroyer type vessels to determine the hydraulic behavior of these systems when connected together in nests. Procedures for connecting and disconnecting nests of ships were developed and documented. The effect of pier sewer system loading by multiple ship sewage discharging was examined. Sewage generation rates from activated CHT systems were also monitored.

Through these field tests most every aspect of CHT transfer systems was examined. The program required the boarding of some 21 ships for the final selection of 11 ships for these tests. As a result, a wide exposure to various shipboard installations was attained.

Testing procedures and results are documented in this report and in a 16mm narrated film report showing the key aspects of CHT ship and shoreside operations.

Shipboard CHT systems and pierside sewers are a simple and effective way to transport shipboard wastewater to shoreside treatment facilities. CHT systems are reliable if proper procedures are understood. When in use, the CHT system is not highly visible and infrequent operator control may lead to problems. Key modifications to control systems and regular maintenance procedures are included in the RECOMMENDATIONS section of this report to help the reliability of the system.

Special shoreside equipment developed by the Public Works Department in San Diego have greatly simplified hose handling to and from ships. Pier sewers have been found to be adequate to handle expected concentrated loading by multiple berthed CHT ships. Procedures for pier operation, particularly for pressure manifolds, should be developed to prevent accidental sewage spills on piers.

Sewage generation rates vary widely between ships depending on habits of salt water use. Regular sewage monitoring for all ships may be required for equitable sewer charges and to limit excessive salt water discharge.

Although this test program could not have been successful without the interest and help of the ships themselves, initial reluctance to use the CHT system limited the number of test candidates and test situations available for tests. Aboard each test ship it was necessary to explain to all levels of command the purpose of the testing program, what would be required by each ship, and if they were willing to activate systems to collect sewage.

As a result of this experience, it is clear that in order to meet the 1981 target date, an effort must be made to "sell" the use of the CHT system to overcome the widespread prejudice against the system. Ports throughout the country other than San Diego should have selected ships activated to provide a visible core of normal CHT activity.

ACKNOWLEDGEMENTS

This ship-to-shore CHT testing program required many long hours of testing several different combinations of ships and piers over the 8 month period. In all cases, the success of the tests was due primarily to the fine cooperation received from both ship and shoreside personnel.

LTjg Carpenter, of COMNAVSURFPAC, was most helpful in providing access to ships and helped coordinate our activities throughout the fleet.

CDR Alexander and Mr. Norm Warner, of San Diego Waterfront Operations, provided continual information on ship scheduling and berthing arrangements for the difficult task of scheduling tests. This help was provided even though it was an extra task for an already difficult job of scheduling ship berthing at the busy San Diego Naval Station.

Special thanks is deserved by the Navy Public Works Center, San Diego, and in particular, Mr. Tom Brule, Mr. Dave Davis, Mr. Bob Miner, for their help with shoreside coordination and help with the engineering aspects of the pier sewers.

The PWC Ship-to-Shore office and particularly Mr. Jack Busbee and Mr. Tom Pendergast, were continuously providing help in the form of hose deliveries, special fittings and encouragement throughout the long test program.

Photographic coverage to document ship and shoreside activities is the result of Chief Carr and his crew from Combat Camera North Island. Without their patience and skill the 15 minute film report would not have been possible.

The actual tests were only possible because of the cooperation received from the test ships. The ships that participated in this testing were:

USS ENGLAND, CG-22
USS JOUETT, CG-29
USS ROARK, FF-1053
USS BROOKE, FFG-1
USS HULL, DD-945
USS STEIN, FF-1065
USS ROANOKE, AOR-7
USS OGDEN, LPD-5
USS SAMUEL GOMPERS, AD-37
USS JOHN PAUL JONES, DDG-32
USS ALBERT DAVID, DD-1050

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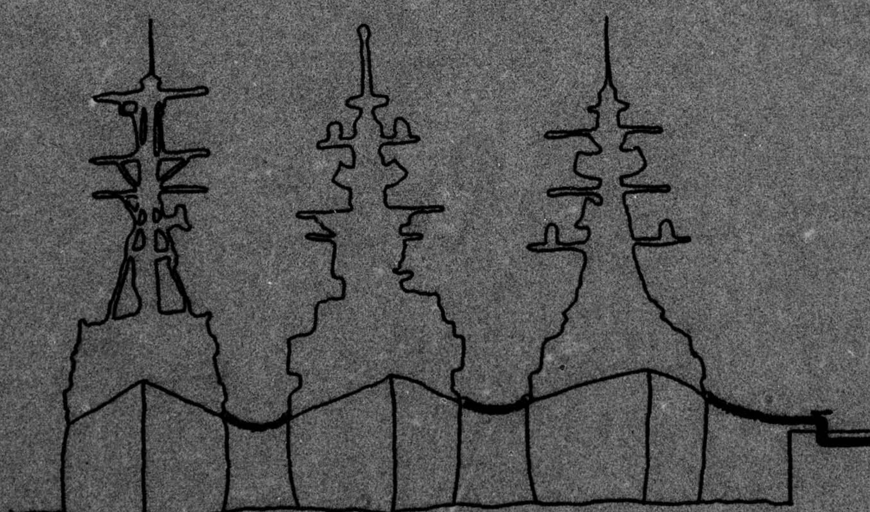
2. BACKGROUND



1. INTRODUCTION

This report describes the results of Sewage Collection, Holding and Transfer (CHT) System field tests conducted with ships and piers at the San Diego Naval Station from February to September, 1977, under contract N00014-77-C-0036. The objectives of the field tests were to:

a. Examine the hydraulic behavior of shipboard CHT systems when interconnected in a berthed nest.

b. Examine the hydraulic behavior of gravity and pressure/gravity pier sewage collection systems with multiple ship berthing conditions.

c. Develop standardized CHT operation and hose handling procedures for nested ships.

d. Update the computer flowrate prediction model, CHTSIM.

e. Monitor sewage generation with CHT systems on destroyer type ships.

The following tests were conducted using actual CHT systems of several destroyer type and larger vessels stationed at the San Diego Naval Station.

Test	Ships Involved
(1) Single Ship Calibration (Establishing hydraulic baseline)	USS ENGLAND, CG-22 USS JOUETT, CG-29 USS ROARK, FF-1053 USS BROOKE, FFG-1
(2) Nested Ship Calibration (Multiple ship hydraulics)	USS ENGLAND, CG-22 USS JOUETT, CG-29
(3) Nested Ships and Tender (CHT hydraulics, procedures and hose handling)	USS SAMUEL GOMPERS, AD-37 USS JOHN PAUL JONES, DDG-32 USS ALBERT DAVID, FF-50

Test	Ships Involved
(4) Gravity Pier Multi-Ship, Pier 4 (Ship and pier hydraulics)	USS ENGLAND, CG-22 USS JOUETT, CG-29 USS HULL, DD-945 USS STEIN FF-1065 USS ROANOKE, AOR-7
(5) Pressure/Gravity Pier Testing, Pier 8 (Pressure manifold hydraulics)	USS OGDEN, LPD-5
(6) CHT Sewage Monitoring	USS ENGLAND, CG-22 USS HULL, DD-945

A description of the specific test procedures and observations with recommendations follows.

2. BACKGROUND

2. BACKGROUND

In response to Executive Order 11752, the Chief of Naval Operations (CNO) directed that the Navy comply with shipboard wastewater discharge regulations by installing Collection, Holding and Transfer (CHT) systems aboard Navy ships. The CHT system is designed to allow for the collection and holding of shipboard generated wastewater, when within three miles of shore, and the transfer of all wastewater to pierside sewers while in port. CHT systems have been installed in approximately 150 ships. Approximately 300 installations are scheduled for completion by 1981. Installation designs were developed by the Naval Ship Engineering Center (NAVSEC), Hyattsville.

Depending on the local situation, sewage is piped to either a Navy treatment facility or a municipal facility under contract. The Naval Facilities Engineering Command (NAVFAC) has the responsibility for the design and installation of pierside sewer pipelines and facilities to receive this wastewater from shipboard CHT systems. NAVFAC has developed two different types of pierside sewer designs. One is a large diameter gravity sewer and the other a gravity sewer combined with a small diameter pressure manifold. Construction has been completed on approximately 200 pier sewers to date.

Single ship CHT system tests have been conducted on the East Coast aboard the USS SURIBACHI (AE-21) and on the West Coast aboard the USS FRESNO (LST-1182). These tests involved the evaluation of available shipboard CHT operation and maintenance.

Although a number of ship CHT systems and pierside sewers have become operational, no quantitative investigation of nested ship hydraulic behavior had been conducted to verify that the combined shipboard systems would operate as intended with the pierside sewer systems. In addition, no detailed techniques and instruction materials had been developed to guide ships' crews and shore personnel in connecting nested ships.

Existing estimates of sewage flowrates from Navy ships had been based on estimates of peak and average flowrates of various ship classes. These estimates have been used to determine ship sewer connection charges and charges by contracted municipalities for sewage treatment. As more ship CHT systems become operational the documentation of actual wastewater generation is necessary for equitable connection charges.

A computer simulation model for predicting sewage flowrates has been developed by NAVFAC and NAVSEC, but no operating data was available to confirm predictions. Flowrate predictions of the model, corrected by field operating data, can more accurately determine maximum offloading flowrates for pier sewer design and peak flowrate connection charges.

The various ship CHT field tests described in this report were performed to provide field evidence that the combined shipboard/pierside sewage systems operate within the bounds of the original design criteria. In addition, valuable documented field experience was gained with actual ship operations to simplify and standardize CHT procedures throughout the fleet and at all Naval shore facilities.

3. SHIP HYDRAULIC TESTING

All field tests were performed with installed shipboard CHT systems. Over 21 ships were boarded to determine their suitability as test candidates. As the objective of the test program was to establish procedures for nested ships, the ships most commonly nested, destroyer type vessels, were the first considered. All CHT systems were inspected to determine that they could pump at least salt water during the proposed tests. In addition, candidates for CHT activation with sewage were selected for sewage generation monitoring. Aboard many of the 21 candidate ships, repairs were made including level sensor modifications, alarm and piping repairs to assist shipboard personnel in preparing for normal CHT pierside operation with sewage.

Based on CHT system condition and ship availability, 11 ships were selected for field testing. All tests were conducted while berthed at the San Diego Naval Station and did not interfere with normal in-port ship activities or underway schedules.

3.1 Single Ship Hydraulic Tests

Single ship hydraulic tests were conducted prior to nested ship testing. The objective of these tests was to isolate individual hydraulic characteristics of the ships that would later be involved in the nested ship tests. Hydraulic data of a single ship could be determined to isolate single ship effects from that of the nest and the data used to update the computer-simulation program CHTSIM.

The single ship tests were conducted by measuring the flowrate and system pressures of the CHT discharge piping at each deck riser, pier discharge riser and the pump discharge to establish a system performance curve. A flowmeter was installed on the sewage discharge hose to record flowrate. Flowrate and back pressures were adjusted by a valve at the pier end of the discharge hose (Figure 1).

FIGURE (1)

INSTRUMENTATION LOCATION (SINGLE SHIP CALIBRATION TESTS)

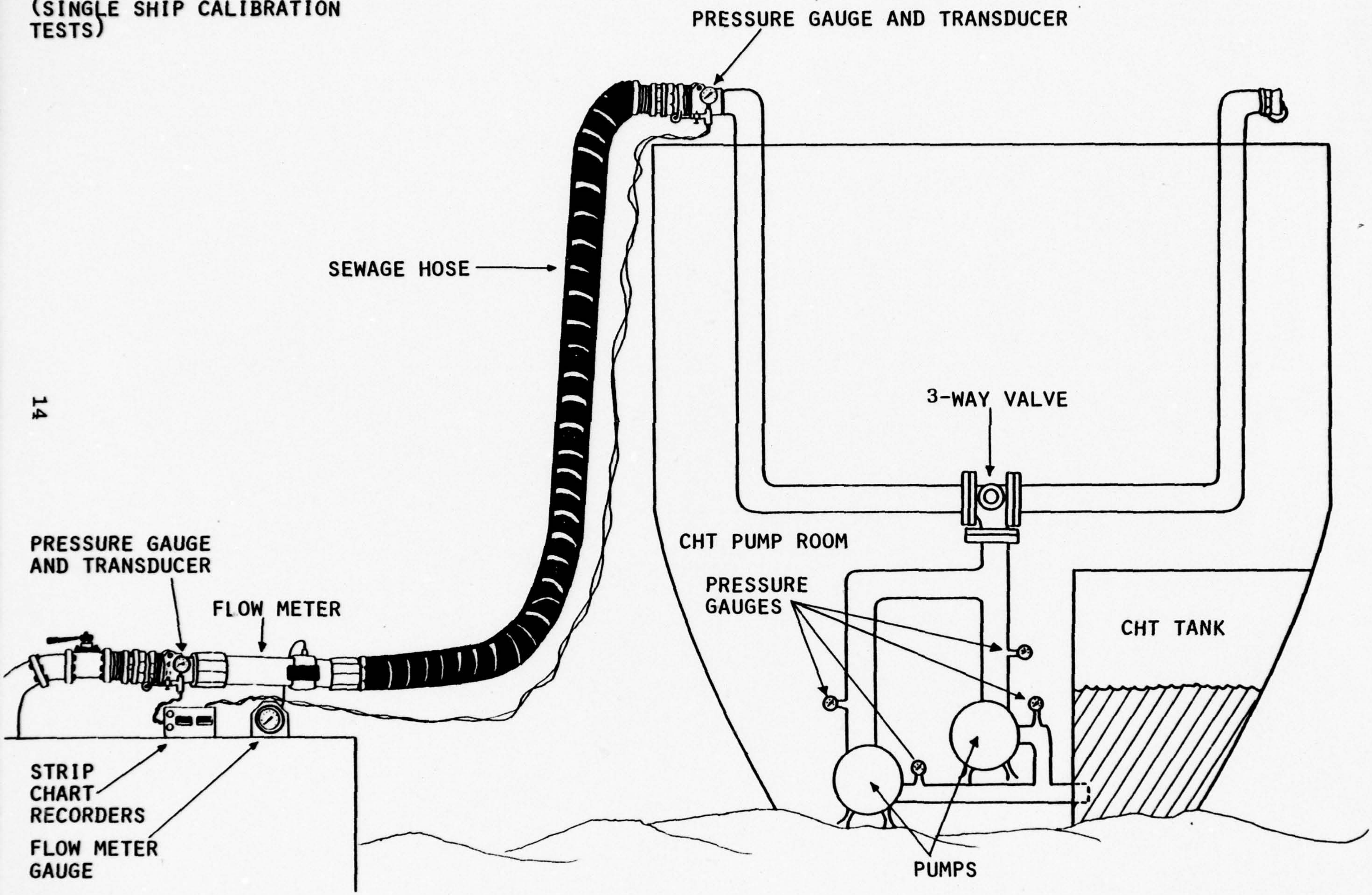
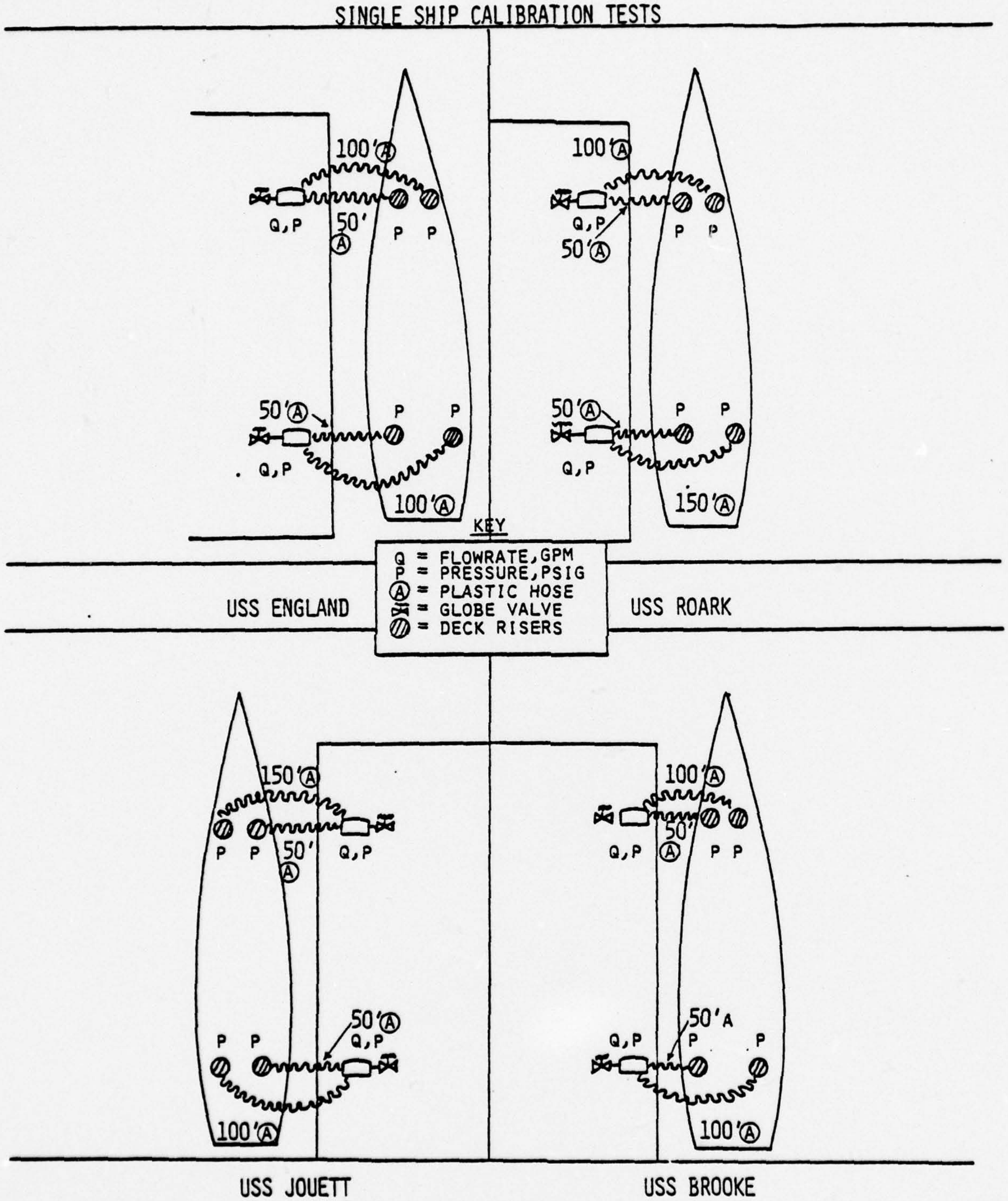


FIGURE 2

SINGLE SHIP CALIBRATION TESTS



For the complete calibration of a single ship, test runs were required for each port and starboard deck riser and both forward and aft systems (Figure 2). Altogether, each ship calibration required at least 10 combinations of pumps and piping directions with an average of 8 data runs each, for a total of at least 80 pump runs for each ship. An average of 3 days was required for the setup of testing equipment and calibration runs for each ship (Figures 3, 4).

Shipboard piping circuits were traced and measured to calculate the hydraulic equivalent lengths so that system curves measured in field tests could be compared with the computer prediction model.

The maximum flowrates are presented in Table 1 for single ship tests. System performance curves are presented in Appendix B.

Observations

1. Velocities in ship discharge piping exceeded 10 ft./sec. under normal pumping conditions.

2. Ships equipped with extensive 3 inch internal discharge piping (USS BROOKE) produced significantly lower flowrates than similar ships equipped with 4 inch discharge piping (see Table 1).

3. Check valve slamming and water hammer were noticed in most ship piping as discharge pumps turned off.

4. Maximum pump discharge pressures ranged from 13 to 22 psi for 1 pump operation. Pressures for simultaneous pumping of 2 pumps in a pumproom ranged from 19 to 24 psi.

5. The discharge flowrate of an open hose was reduced approximately 20% when connected to the Pier 5 pressure sewer. Similar choking of flow was observed on Pier 4 gravity system.

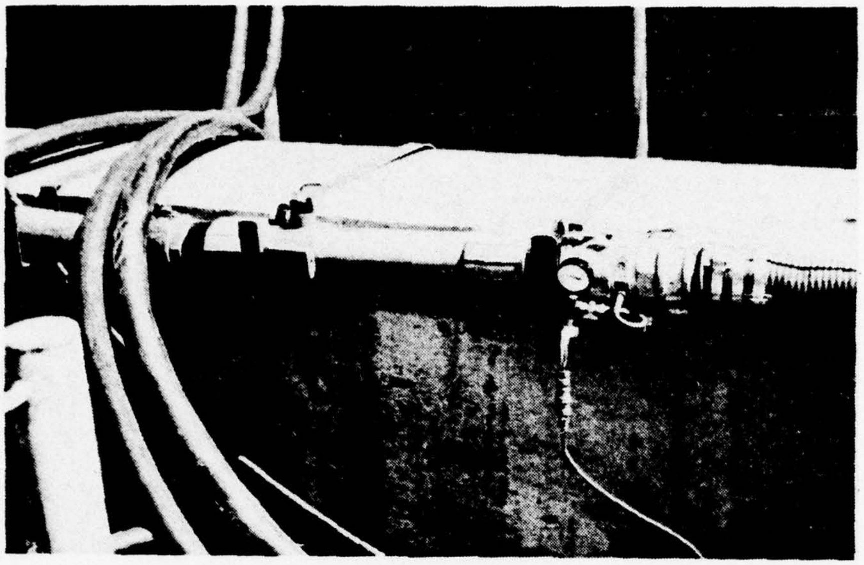


FIGURE 3
FLOWMETER AND PRESSURE GAUGE

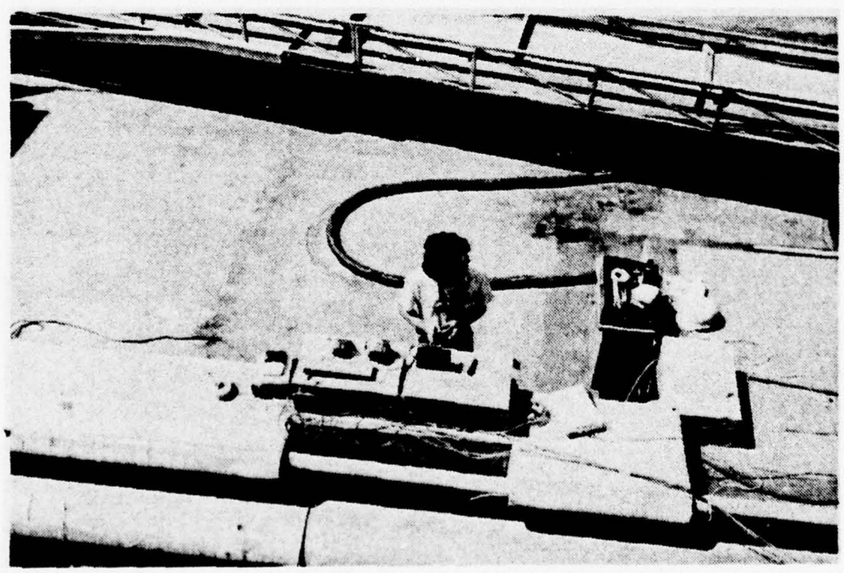


FIGURE 4
PIERSIDE DATA STATION

TABLE 1

SINGLE SHIP HYDRAULIC TESTS

MAXIMUM CHT PUMP FLOWRATES AND RELATED PRESSURES

		Flow Rate (GPM)	Pump Discharge Pressure (PSI)	Deck Riser Pressure (PSI)	Pier Riser Pressure (PSI)
USS JOUETT	Fwd - Pump #1	360	16.1	-2.5	0.0
	Fwd - Pump #1 & #2	490	23.0	-1.0	0.0
(pumping into Pier 4)	Fwd - Pump #1 & #2	540	24.1	0.9	2.9
	Aft - Pump #1	420	17.8	0	3.9
	Aft - Pump #1 & #2	600	23.0	3.9	0.0
USS ROARK	Fwd - Pump #2	410	21.0	-1.0	0.0
(pumping into Pier 5)	Aft - Pump #1	380	18.6	3.4	3.9
(pumping into Pier 5)	Aft - Pump #1 & #2	500	24.5	9.2	7.8
USS ENGLAND	Fwd - Pump #1	430	14.3	-5.1	0.0
	Fwd - Pump #1 & #2	640	21.0	2.0	0.0
	Aft - Pump #1	390	14.6	-3.2	0.0
	Aft - Pump #1 & #2	570	20.4	2.4	2.4
USS BROOKE	Fwd - Pump #1	310	20.8	-3.0	0.0
	Fwd - Pump #1 & #2	395	24.3	2.0	0.0
	Aft - Pump #1	320	21.5	-2.2	0.0
	Aft - Pump #1 & #2	390	24.7	0.0	0.0

6. Pump head vs. flowrate curves developed from the field data were consistently lower than the manufacturer's curve at low flowrates. For a given discharge head the measured flowrate was less than predicted by manufacturer's curves at low flowrates. At flowrates above 350 gpm the measured pump head was somewhat greater than expected.

3.2 Nested Ship and Pier Hydraulic Tests

For these tests, 2 cruisers, the USS ENGLAND and the USS JOUETT, were berthed alongside Pier 4 in a nest as shown in Figure 5. The JOUETT was berthed outboard of the ENGLAND and discharged through the internal CHT piping of the ENGLAND into Pier 4.

The objective of these nested ship hydraulic tests was to determine the hydraulic characteristics of ships using their CHT systems while interconnected in a nest. Also, possible CHT system failure modes were simulated to determine the effect on offloading of sewage to pierside from the nest.

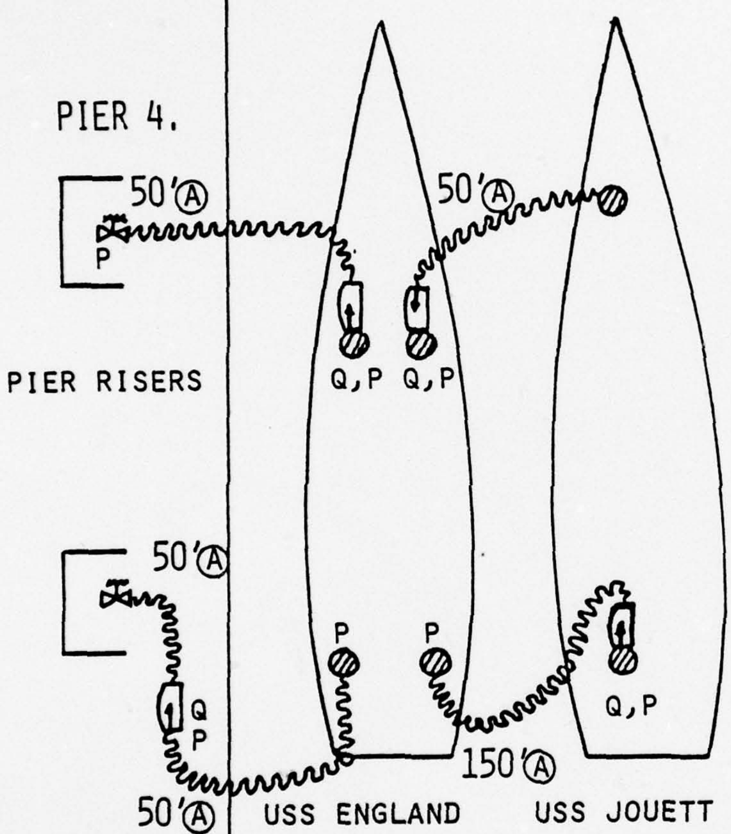
During these tests, both ships were operating their CHT systems and collecting sewage in the normal manner. Tests were performed by supplementing the ships' collected sewage with salt water to provide a sufficient pumping volume. Flowmeters were installed on each ship and pressures recorded for each pump deck riser and pier discharge (see Figures 5, 6, 7 and 8).

To determine the characteristics of each interconnected CHT system, several pumping combinations were tested. These combinations included measuring the discharge from a single pump in the nest, 1 pump in each pumproom, 3 pumps and 4 pumps. Seven data runs were required for each of the above pump combinations. These tests were repeated for each shipboard CHT system. Approximately 70 data runs were required for the full nest determination of connected ship hydraulics.

Maximum flowrate tests were conducted for the total nest discharge into Pier 4. Pumps in each of the 4 pumprooms were operated simultaneously. Test runs of 1 pump in each pumproom (4 total) and 2 pumps in each pumproom (8 total) were conducted and the maximum flow into the gravity pier sewer system (Pier 4) was measured. Results are presented in Table 2.

Backflow tests were conducted to determine if inner ship backflow would occur between the nested ships. During the first

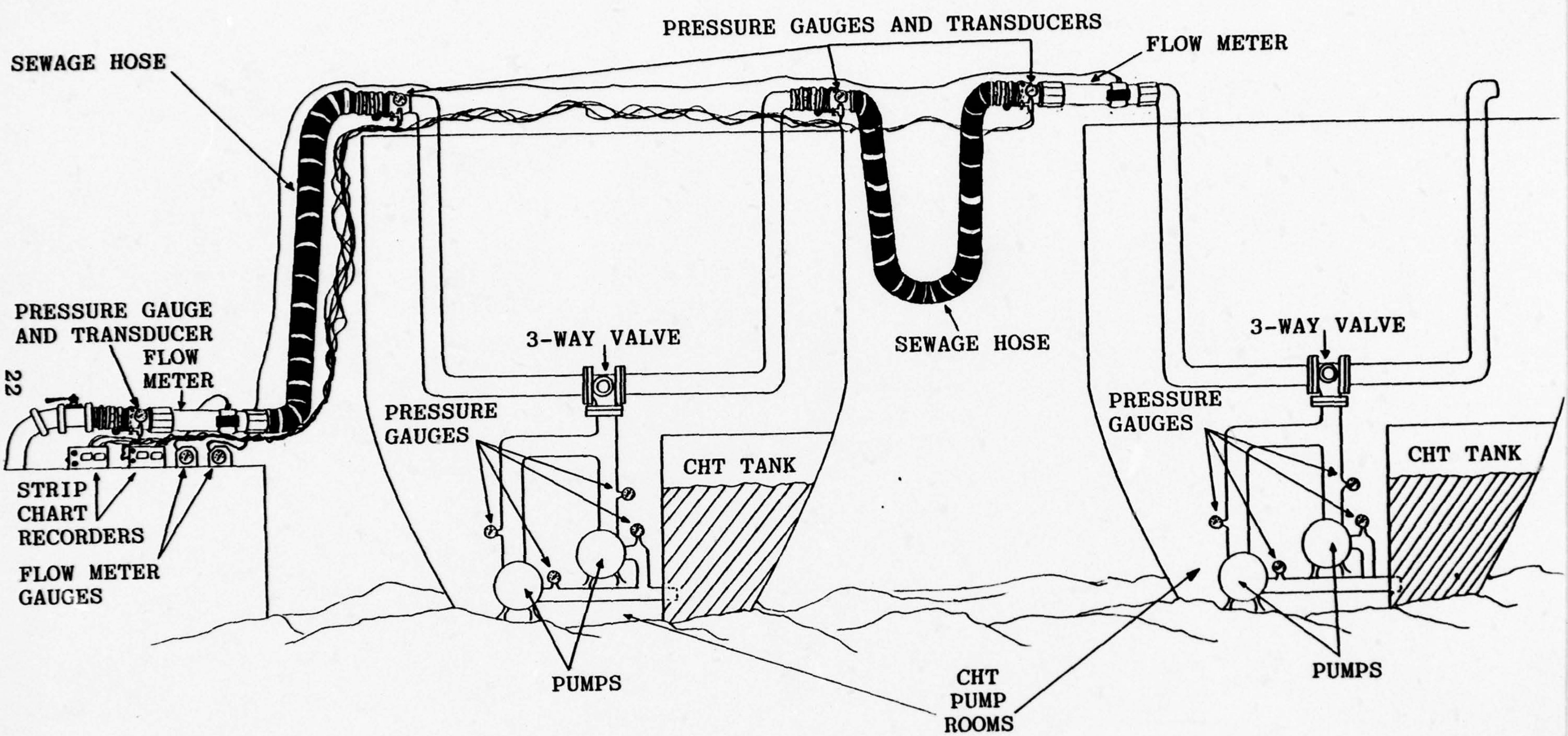
FIGURE 5
NESTED SHIP CALIBRATION TESTS



KEY
Q = FLOWRATE, GPM
P = PRESSURE, PSIG
(A) = PLASTIC HOSE
⊠ = GLOBE VALVE
⊘ = DECKRISERS

FIGURE 6

INSTRUMENTATION LOCATION (NESTED SHIP CALIBRATION TESTS)



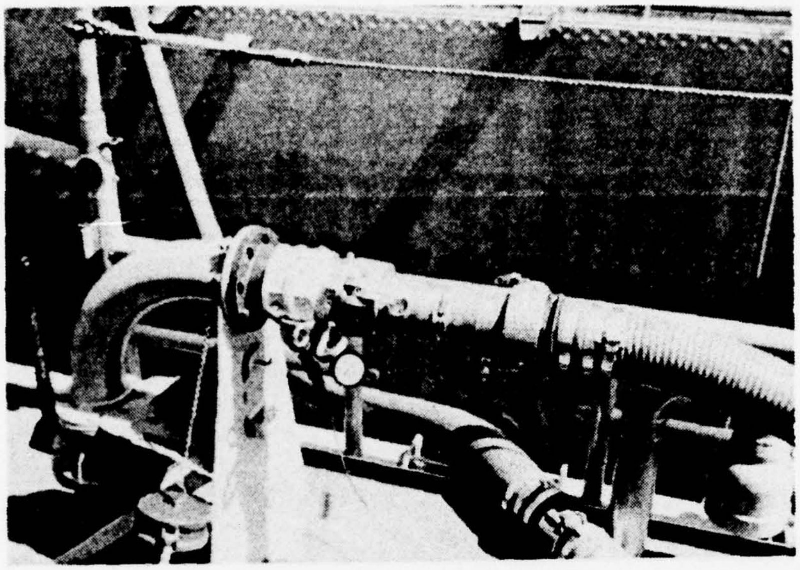


FIGURE 7
DECK RISER WITH ADAPTER AND PRESSURE TRANSDUCER

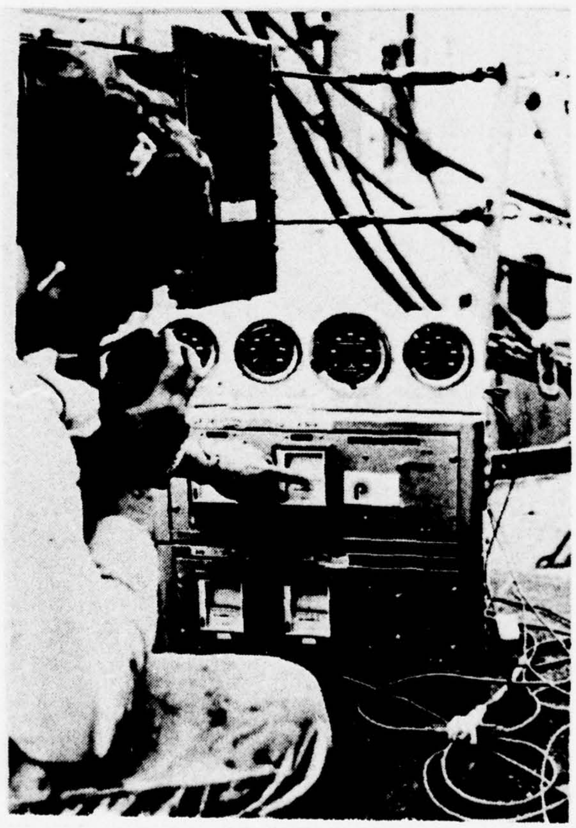


FIGURE 8
DATA CONTROL STATION

TABLE 2

NESTED SHIP HYDRAULIC TESTS

MAXIMUM CHT PUMP FLOWRATES AND RELATED PRESSURES

	Flow Rate (GPM)	Pump Discharge Pressure (PSI)	JOUETT Port Deck Riser Pressure (PSI)	ENGLAND Deck Riser Pressure (PSI) Stbd.	ENGLAND Deck Riser Pressure (PSI) Port	Pier Riser Pressure (PSI)
Forward Pumprooms - ENGLAND & JOUETT:						
JOUETT - Pump #2	350	22.0	9.5	9.0	9.0	3.0
JOUETT - Pump #1&#2	450	27.5	11.0	6.5	10.0	0.5
ENGLAND - Pump #1; JOUETT - Pump #2	640 E = 360 J = 280	E = 21.0 J = 26.0	12.0	8.5	13.5	0.5
ENGLAND - Pump #1; JOUETT - Pump #1&#2	680 E = 320 J = 360	E = 20.0 J = 30.0	15.5	10.0	16.5	1.0
ENGLAND - Pump #1&#2; JOUETT - Pump #1&#2	780 E = 470 J = 310	E = 25.0 J = 30.0	17.5	12.0	19.0	1.0
Aft Pumprooms - ENGLAND & JOUETT:						
JOUETT - Pump #2	320	24.0	6.5	1.5	4.5	5.0
JOUETT - Pump #1&#2	410	33.0	13.5	3.5	8.5	6.5
ENGLAND - Pump #1; JOUETT - Pump #2	540 E = 320 J = 220	E = 23.0 J = 29.0	14.0	7.0	13.0	8.0
ENGLAND - Pump #1; JOUETT - Pump #1&#2	600 E = 300 J = 300	E = 23.0 J = 34.0	19.0	8.5	5.5	9.0
ENGLAND - Pump #1&#2; JOUETT - Pump #1&#2	660 E = 400 J = 260	E = 27.0 J = 34.5	20.5	10.0	19.0	9.5
All Pumprooms						
ENGLAND & JOUETT - Pumping into Pier 4:						
1 Pump Operating	Fwd total = 610 Aft total = 420					
2 Pumps Operating	Fwd total = 790 Aft total = 560					

of these tests, pump discharge check valves on the inboard ship were jacked open to simulate a check valve failure so that flow from the outboard ship would enter the CHT tank. The outboard ship's pumps were activated and the effect of inner ship flow was determined. Tests for the opposite failure condition were also conducted. And, in addition, the pier riser valve was closed during shipboard offloading to simulate an accidental closure. System pressures were recorded and system inspected for leaks.

Observations

1. While ships are pumping and connected in a nest, the flowrate from the outboard ship will be reduced if the inboard ship is also pumping. The combined flowrate with one pump from each pumproom is approximately 80% of the sum of the individual flowrates. With two pumps from each pumproom the combined flowrate is approximately 70% of the sum of the flows from individual pump-rooms with two pumps.

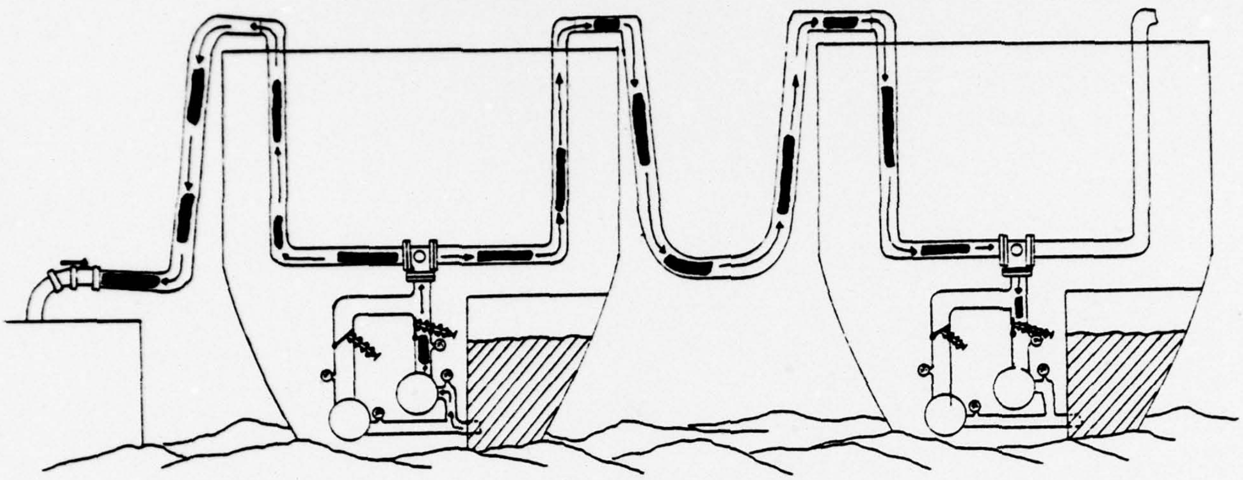
2. Flow velocities in some sections of ships piping will exceed 10 feet per second if more than one pump is operating in the same piping circuit.

3. Backflow occurred when check valves were opened on the inboard ship of the nest (see Figure 9). Flowrates of 150 gpm aft and 360 gpm forward into the inboard ships' tanks were observed. No backflow was observed when the outboard ships' check valves were opened and the inboard ship was pumping (see Figure 9a).

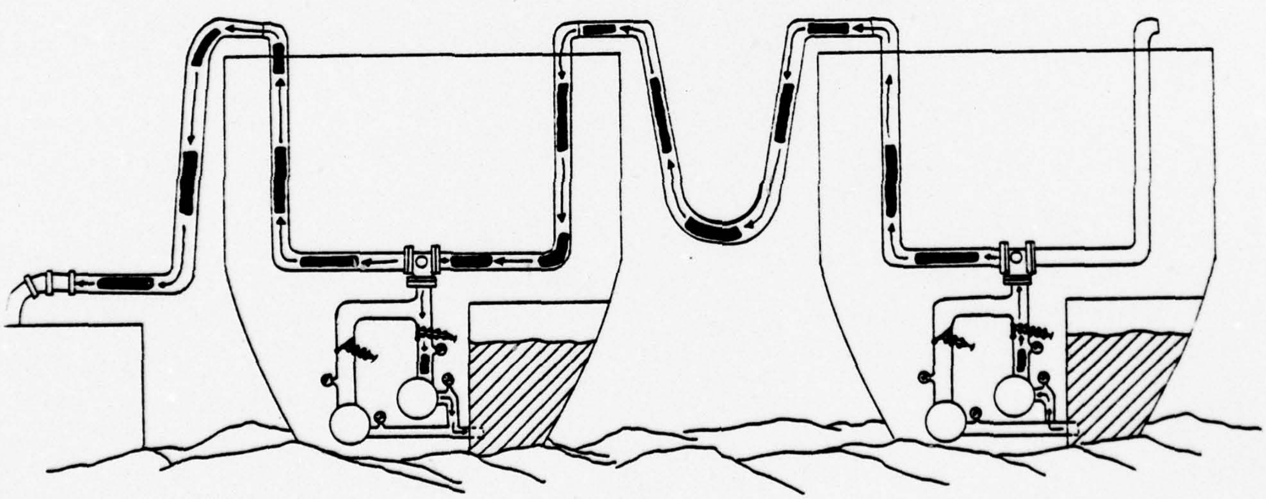
4. When backflow did occur the level in the receiving tank would fill to the 30% level and activate the discharge pump in the normal manner. During backflow into the inboard ship CHT tanks, pump shafts were observed to counter-rotate at high speed.

FIGURE 9

NESTED SHIP BACKFLOW TESTS



(A)
Inboard Ship Pumping
Check Valve On Outboard Ship Opened



(B)
Outboard Ship Pumping
Check Valve On Inboard Ship Opened

5. With the pier riser valve closed, shipboard CHT pump discharge pressures increased to 40 psi. No piping or hose leakage was observed when the pier riser was closed during pumping.

3.3 Nested Ships and Tender

For these tests, a nest was formed with the USS JOHN PAUL JONES and the USS ALBERT DAVID outboard the tender USS SAMUEL GOMPERS. The destroyers were connected together to pump through the hull of the inboard ship and discharge to the GOMPERS (Figure 10).

The nest was connected from forward and aft systems and discharged to the aft mooring station of the GOMPERS. Flowmeters were connected to each system discharge and pressure gauges installed. The test configuration and related instrumentation are shown in Figure 11.

The purpose of these tests was to identify the hydraulic behavior of this nest situation and to identify any ship connection problems. Tests were conducted to simulate all normal system operations, such as simultaneous ship pumping, an arriving ship, a departing ship and maximum system flowrates (Table 3). The normal 30% and 60% tank pumpdown time was also determined (Table 4).

Observations

1. Choking of pump flows from the forward CHT pumps of the ALBERT DAVID was observed when 1 or 2 pumps in another pumproom were operating simultaneously. Choking could be identified by the sudden surge of flow observed when pumps shut off in the other pumproom. This choking was not consistently observed.

2. The CHT equipped mooring stations aboard the GOMPERS were difficult to access when connecting the forward deck riser of the JOHN PAUL JONES to the GOMPERS. The forward CHT equipped mooring station on the GOMPERS was located 100 to 150 feet beyond the bow of the JOHN PAUL JONES. The connection to the GOMPERS was made by running 250 feet of hose from the forward deck riser aft along the starboard main deck of the JOHN PAUL JONES and connecting to the aft mooring station of the GOMPERS, see Figure 12.

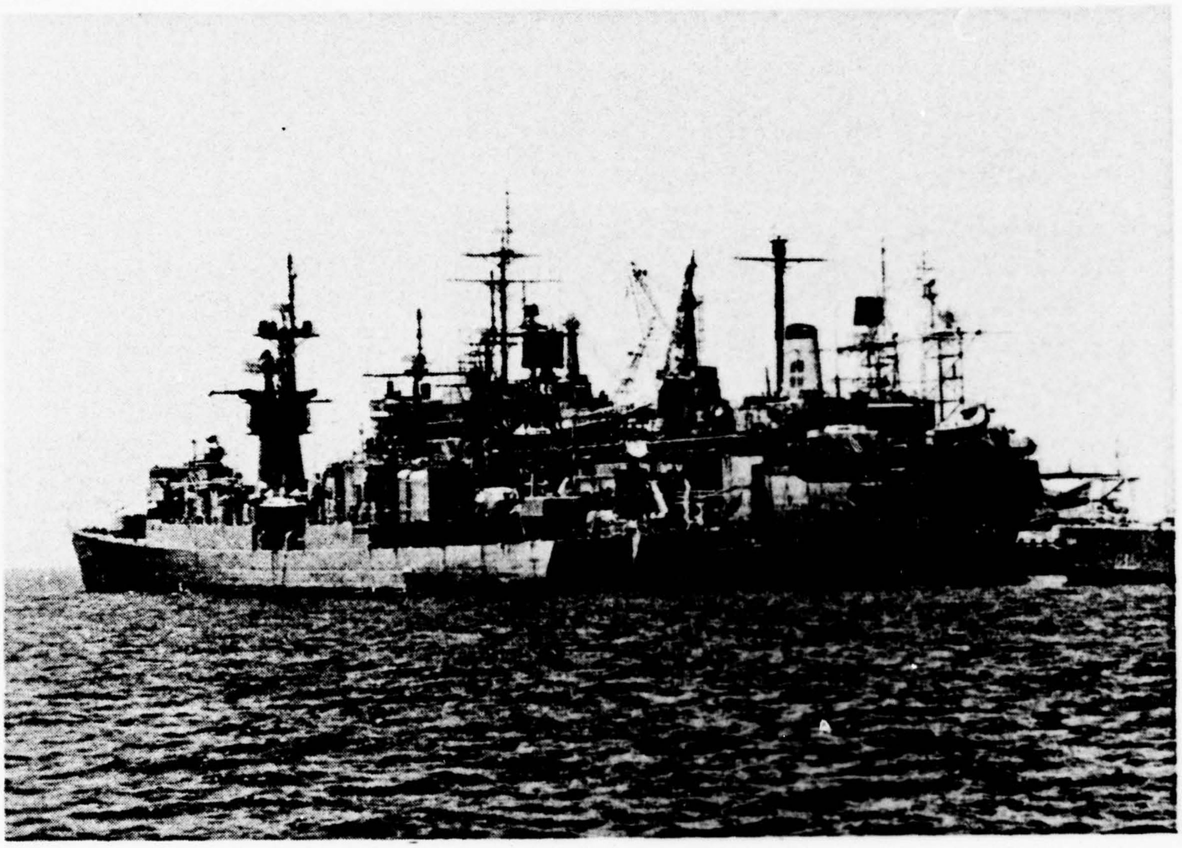


FIGURE 10

DESTROYER NEST WITH TENDER

FIGURE 11

NEST OUTBOARD A TENDER

KEY

Q = FLOWRATE, GPM
P = PRESSURE, PSIG
Ⓐ = RUBBER HOSE (FLAT)
Ⓑ = RUBBER HOSE (FULL BORE)
(hatched circle) = DECK RISERS

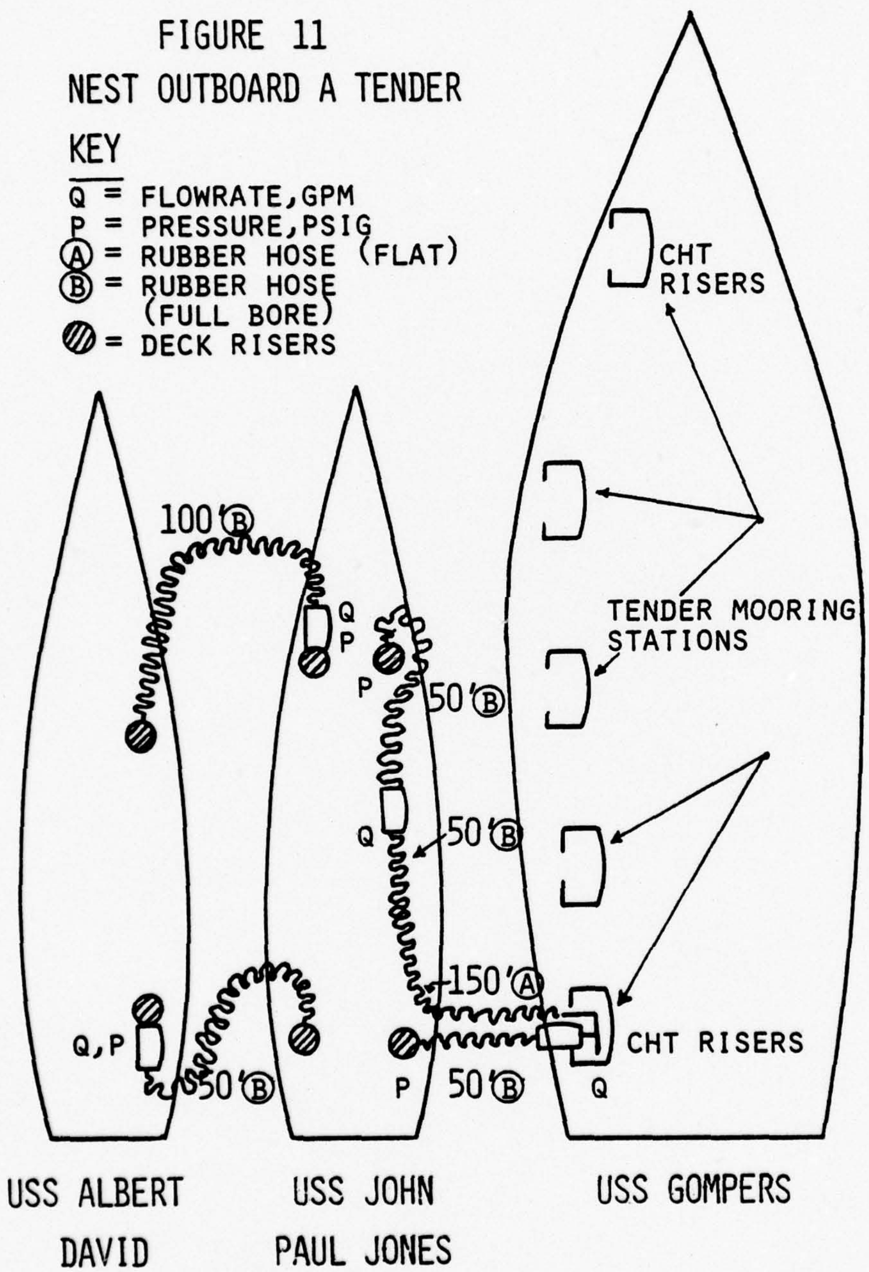


TABLE 3

NEST OUTBOARD A TENDER

MAXIMUM CHT PUMP FLOWRATES AND RELATED PRESSURES

Run No.	Ships Pumping	No. of Pumps	Flowrate (GPM)	Deck Riser Pressure (PSI)
1	J.P. JONES Aft	2	650	4.0
2	J.P. JONES Fwd	2	280	9.0
3	J.P. JONES Aft	1	440	4.0
	A. DAVID Aft	1	180	12.0
4	J.P. JONES Fwd	1	230	0.0
	A. DAVID Fwd	1	130	-
5	J.P. JONES Aft	1	430	0.0
	A. DAVID Aft	2	240	15.5
6	J.P. JONES Fwd	1	220	10.0
	A. DAVID Fwd	2	150	-
7	J.P. JONES Fwd & Aft	1 ea.	F = 300 A = 360	F = 10.5 A = 7.0
	A. DAVID Fwd & Aft	1 ea.	F = 0 A = 150	F = - A = 17.0
8	J.P. JONES Fwd & Aft	1 ea.	F = 240 A = 380	F = 10.0 A = 7.0
	A. DAVID Fwd & Aft	1 ea.	F = 80 A = 120	F = - A = 17.0
9	J.P. JONES Fwd & Aft	2 ea.	F = 190 A = 450	F = 11.0 A = 8.5
	A. DAVID Fwd & Aft	2 ea.	F = 100 A = 130	F = - A = 20.5
10	J.P. JONES Fwd & Aft	2 ea.	F = 330 A = 470	F = 12.0 A = 8.5
	A. DAVID Fwd & Aft	2 ea.	F = 0 A = 120	F = - A = 21.0

TABLE 4

TIME FOR PUMPDOWN - ONE PUMP PER PUMPROOM

Tank Level	Forward CHT Tank	Aft CHT Tank
	USS JOHN PAUL JONES	
30%	56 sec.	32 sec.
60%	185 sec.	135 sec.
	USS ALBERT DAVID	
30%	19 sec.	18 sec.
60%	60 sec.	48 sec.

3. One hundred fifty feet of collapsible rubber sewage hose was used to make part of the connection to the GOMPERS. Kinking in this collapsible hose stopped the flow from the forward CHT systems, see Figure 13.

4. During check valve failure tests aboard the outboard ship, backflow occurred at approximately 240 gpm when the inboard ship was pumping.

5. Flow from the outboard ship was choked off significantly when 1 or 2 pumps in the same piping circuit aboard the inboard ship were operating.

6. Because the forward and aft system discharges were connected to the same riser on the GOMPERS, flow from both fore and aft systems was choked when pumps in both circuits were operating simultaneously, see Figure 14.

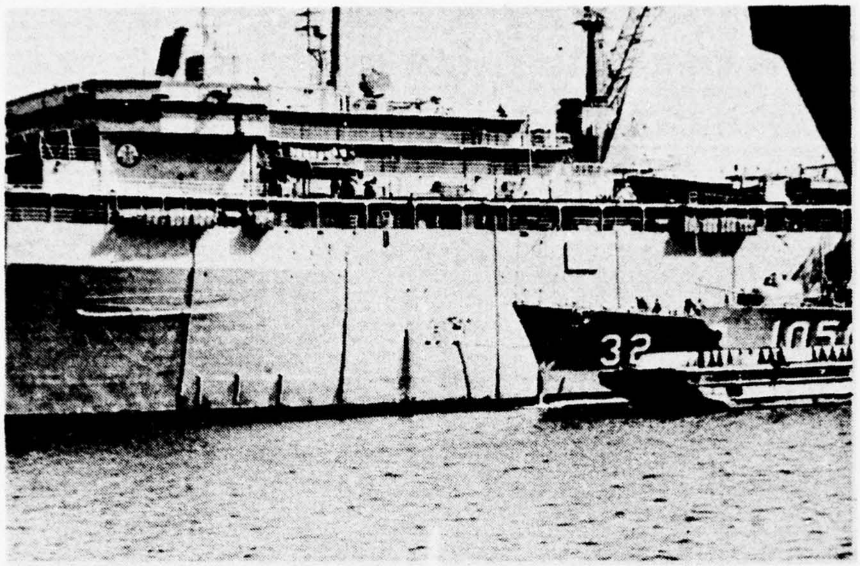


FIGURE 12

FORWARD MOORING STATION OF GOMPERS (LEFT)

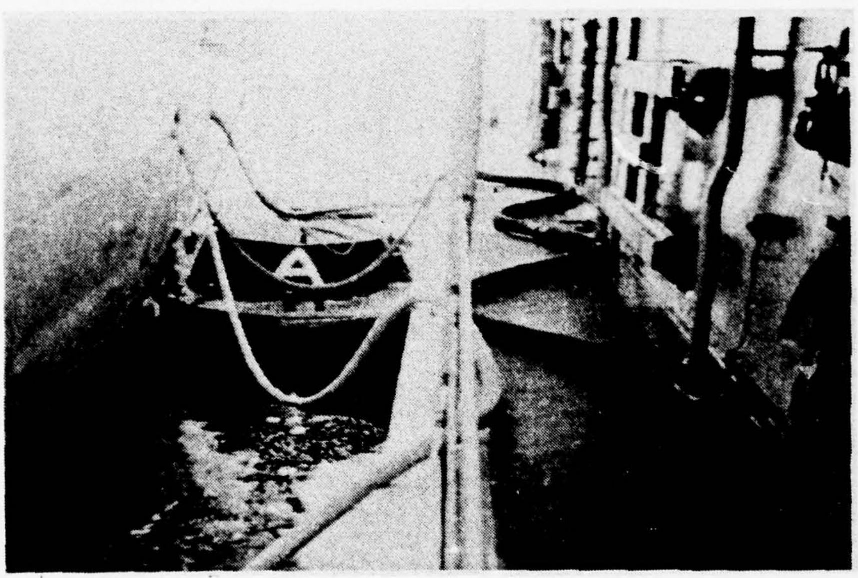


FIGURE 13

KINKED CHT DISCHARGE HOSE ON DECK

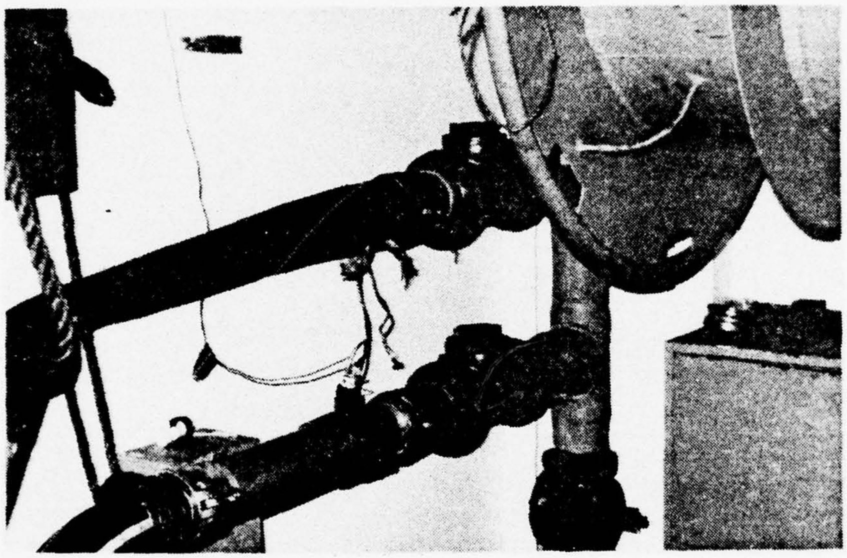


FIGURE 14

COMMON RISER AT AFT MOORING STATION OF GOMPERS

3.4 Test Conclusions

Single Ships

1. The maximum flowrate that can be developed by an individual 70 ft. maximum discharge head sewage installed aboard CG, FF, DD, DDG, and FFG classes of ships when connected to a pier is approximately 430 gpm.

2. The maximum pump discharge pressure noted during normal operating conditions is approximately 34 psi.

3. Pressures at shipboard deck risers will range from -5 psi to +20 psi under normal operating conditions depending on the elevation of the deck riser above the pier riser. Deck riser pressure will be negative when the ships are not pumping.

4. Pressures at the pier risers on a gravity pier system should not exceed 10 psi under normal conditions.

5. All 4 inch piping and hose used in present CHT systems will have flows exceeding 9 feet per second during normal CHT operation.

Nested Ships

1. Pumps installed in CHT systems operated at lower discharge heads than predicted by manufacturer pump curves. This condition was most probably the result of variations in impellor adjustments and clearances. Variations in the test pump curves and manufacturer's curves were also due to the difference between the experimental setups used at the factory and those existing in the field.

2. The maximum flowrates that can be developed by 2 CHT pumps operating simultaneously in each of 2 pumprooms (4 pumps pumping) while connected in a nest is approximately 790 gpm.

3. While connected in a nest, CHT systems should have no problem in handling backflow if check valve failures occur.

4. Ships outboard in a nest can transfer sewage to piers through inboard ship CHT piping with no adverse effects. Under certain conditions some pumprooms in a nest may not be able to pump if all the pumps in the nest are operating simultaneously. This situation should not last more than a few minutes and would not cause a CHT tank to overflow if normal sewage generation rates existed at the time.

5. Pier riser valves can be closed during ship pumping without damage to plastic hose or piping.

3.5 CHTSIM Comparison and Update

The CHTSIM model is a computer program that was developed for use as a pier design aid for NAVFAC. The program provides as output a single "equivalent" pump curve which can be used by designers to size piping for pier CHT sewage systems. For single ships with more than one pump per CHT pumproom operating, or for a nest of ships with various combinations of pumps activated, the program calculates and prints out a single "equivalent" pump curve which would appear to an observer stationed at the pier riser valve. In the original development of CHTSIM, assumptions were made in selecting the friction factors for shipboard piping and ship/shore sewage discharge hose. In addition, the piping dimensions of internal ship piping were estimated. The accuracy of the computer model was limited due to the above assumptions. Data generated by these field tests can be used to update the computer model.

Comparison of Hydraulic Data

Comparisons between the computer model and actual field data were developed by calculating field measured pump curves and line loss data in accordance with the method used by the CHTSIM program. Comparisons were then made between the flowrate at the open hose discharge, measured in the field, and the flowrate predicted by the CHTSIM computer method using the standard line loss and pump curves provided in the original program.

These results were compared with predictions made by using an average pump curve and an average piping line loss. These averages were the result of actual field test pump data and the measured equivalent piping lengths for each test ship.

Graphs used to make flowrate predictions are shown in Appendix B.

For single ships, the difference between actual flowrates measured in the field and flowrates predicted by the corrected

computer program, using an averaged pump curve and the averaged ship line loss, ranged from +13 to -14%. Computer predictions using actual pump curves and line loss measurements for individual ships ranged from +10 to -11%.

From nested ship tests, computer predictions of flowrates using field measured pump curves and measured internal equivalent lengths underestimated actual field measured flowrates by 9 to 13%.

CHTSIM Data Update

Equivalent lengths and other hydraulic data for 4 classes of ships are presented in Table 5. The data is arranged in a format suitable for use by the CHTSIM program.

The equation used in subroutine ADDCRV for the ship piping friction factor should be altered to:

```
FX = 0.75*(0.0135 + (2.7183**((2.95) + (-.705*ALOG(RX-500)))))
```

This equation will yield friction factors for pipe for the relative roughness of .0002 and corrects the head loss in pipe by reducing it by 25%.

The equation used in subroutine ADDCRV for the hose line loss friction factor should be altered to:

```
FHOSE = 0.0265 + (2.7183**((3.50) + (-.877498*ALOG(RX-5000))))
```

This equation will yield a friction factor based on relative roughness of .0035. The pump curves used in the present program should be retained even though they yield higher flowrates for a given head observed in the field tests. Flowrate predictions will tend to be overestimated to provide an additional safety factor for design.

TABLE 5

SHIP HYDRAULIC DATA FOR CHTSIM UPDATE

Class	LEAHY (CG)		BELKNAP (CG)		KNOX (FF)		BROOKE (FFG)	
Ship	ENGLAND (CG-22)		JOUETT (CG-29)		ROARK (FF-1053)		BROOKE (FFG-1)	
	Forward	Aft	Forward	Aft	Forward	Aft	Forward	Aft
Pump Type (max. hd., ft. H_2O)	70*	70	70	70	70	70	70	70
Number of Tanks	1	1	1	1	1	1	1	1
Equivalent Length								
Intersection to port deck riser (ft.)	112	234	225	147	183	155	230	546
Intersection to starboard deck riser (ft.)	124	147		103	125	82	348	345
Pump suction to Intersection (ft.)	358	187	267	288	508	335	504	420
Height of intersection above (+) or below (-) ship's waterline (ft.)	+10.6	-5.8	+12.7	+5.20	+5	+3.5	+15	-5.5
Height of 30% sewage level in CHT tank above (+) or below (-) the ship's waterline (ft.)	-3.0	-7.2	-1.5	-1.9	-5.4	-4.25	-4.5	-7.4
Reference Tank Volume (gal.)	230	170	165	250	260	215	255	275

*Pump Code 4 in CHT Ship/Shore Interface Information Book

4. SHIP AND PIER TESTING

A series of tests were conducted both on the gravity pier piping system (Pier 4) and a pressure/gravity pier system (Pier 8) at the San Diego Naval Station to examine ship and pier interaction. With most ships, CHT systems were tested using salt water pumped by the CHT discharge pumps. On some ships testing was done using their CHT systems while collecting sewage which was supplemented with sea water for test purposes.

4.1 Gravity Pier Loading Tests (Pier 4)

Tests of the Pier 4 gravity sewer system were conducted with multiple ships berthed at the pier. The ships used in this series of tests were the USS JOUETT, USS ENGLAND, USS HULL, USS STEIN, and the USS ROANOKE. The tests were conducted to examine the effect of high flowrates on a gravity pier sewer. Several pumping combinations were tested to examine possible choking of flowrate by the pier piping and backflows through open pier risers.

The five test ships were berthed in two nests at the far end of Pier 4 and a single berthed ship at the near end of the pier. Four of the ships had 2 CHT systems each with 2 pumps in each pumproom. The ROANOKE had 3 CHT systems with 2 pumps each. These 5 ships together contain 11 pumprooms and 22 discharge pumps. The test layout is shown in Figure 15.

As the inboard ships of each of the nests were not fitted for through-hull sewage transfer, it was necessary to lay hose over the decks of the inboard ships and join the flows with "Y" fittings into a common pier riser (Figure 16). Both full bore plastic and collapsible rubber hose were used for these tests. It was necessary to carefully support the collapsible black rubber hose to prevent kinking which could restrict or completely shut off CHT discharge flows.

Discharge from the 11 pumprooms were connected to 7 pier risers. Flowmeters and pressure gauges were connected to each pier riser.

A simple sight tube and measuring scale was rigged in the pumproom of the pier wetwell to measure the collected liquid level and filling rate from ship pumping (Figure 17).

During the test, all 11 pumprooms and the pier wetwell were connected to a central data control station by a temporary sound-powered phone circuit, using over a mile of wire, rigged for this test. Through the sound-powered phones the pumping sequence could be controlled and the status of tank filling monitored (Figure 18).

The results of the tests are listed in Table 6. In test series A, maximum flow tests were conducted with the ROANOKE. The CHT tanks in each of 3 pumprooms were filled to the 60% level. On command from the pier, the pumps were operated for 30 seconds. Flowrates from each pumproom and pier risers were measured both at the riser and in the pier wetwell. Tests were repeated 3 times to establish repeatability of the data.

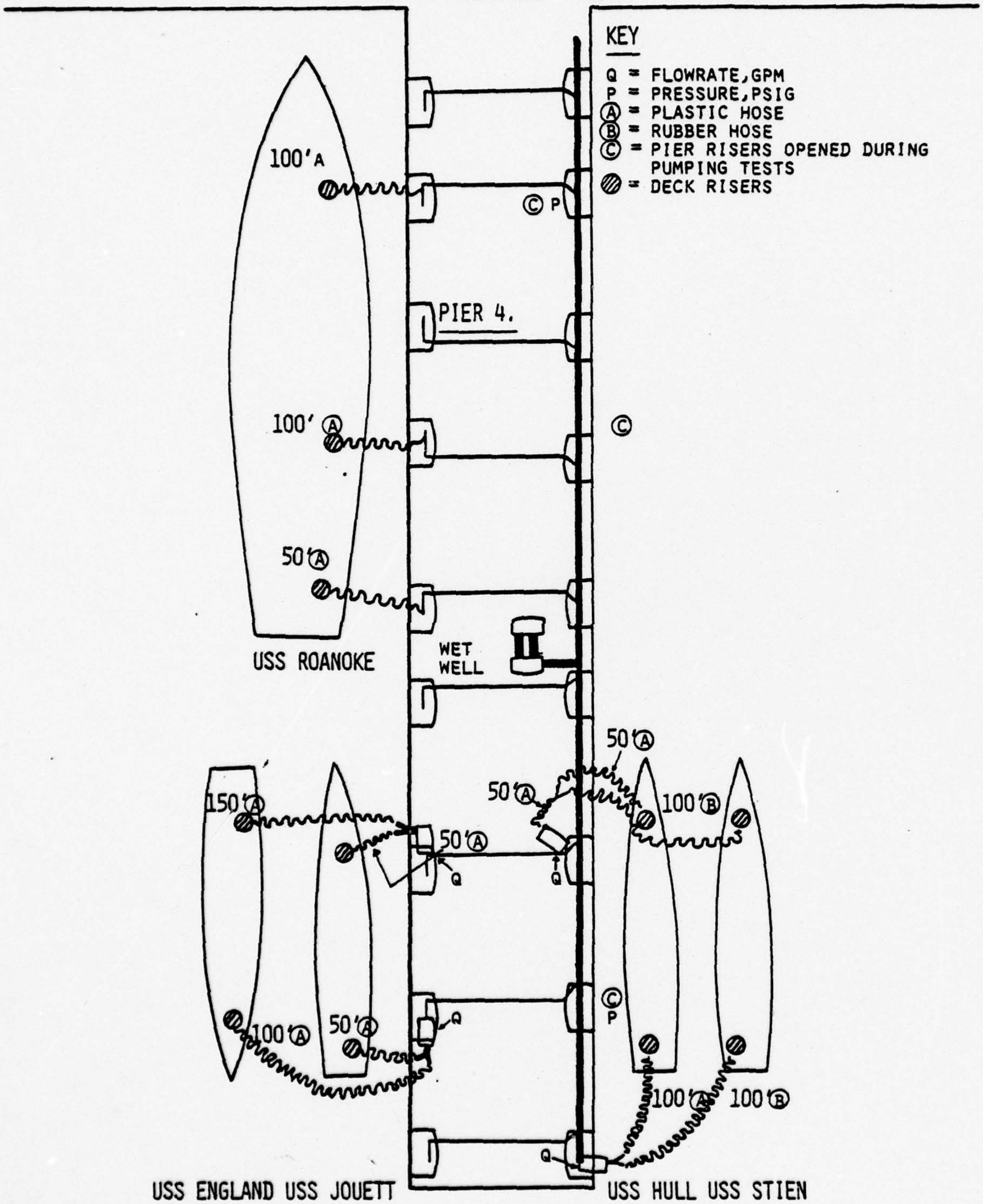
Next, all 6 pumps on the ROANOKE were activated. The pier valve opposite the forward pier connection of the ROANOKE was open while the pumps were operating and an inspection for backflow out of the riser was made. This test was repeated using various cross pier risers for evidence of backflow.

For test series B and C, maximum flow tests were conducted with the nested ships. One pump in each of the four ships' pumprooms and then 2 pumps in each of the ships' pumprooms were activated. Measurements were taken of the flowrate from the four ships into the pier by flowmeters and pressures into pier risers were measured. The flow into the pier wetwell was also measured.

In the test series D and E, flow from all of the ships and all pumprooms was measured. First, a total of 14 pumps were activated and flows measured into the pier and into the wetwell. Next all pumps on all ships, 22 pumps and 11 pumprooms, were turned on simultaneously. Flows were measured into the pier and at the wetwell. The test results for all 3 maximum flowrate tests are presented in Table 6.

FIGURE 15

PIER 4. MULTI-SHIP TESTS



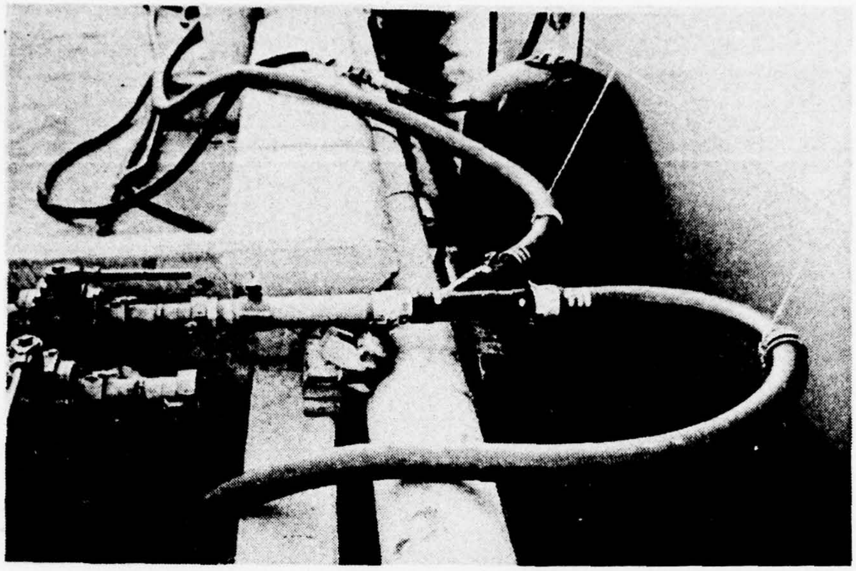


FIGURE 16

"Y" FITTING JOINING DISCHARGE HOSES

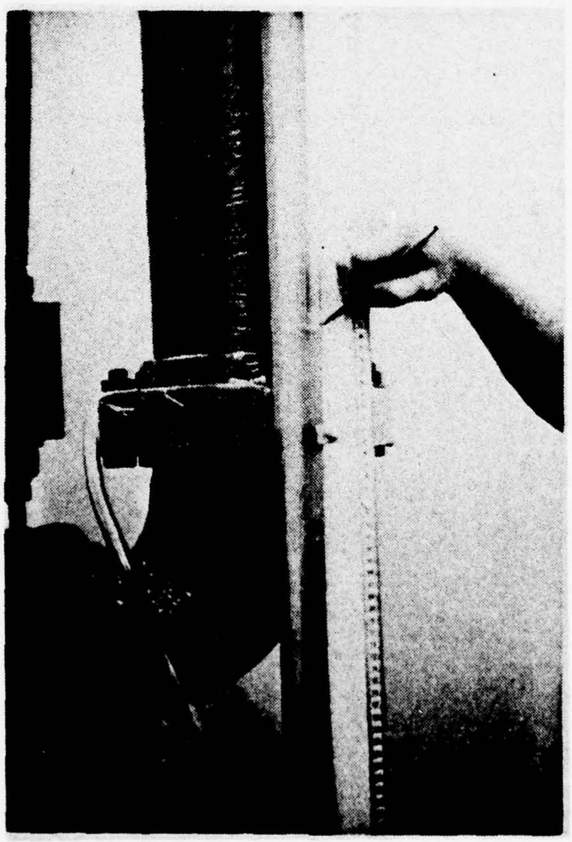


FIGURE 17

WET WELL LEVEL GAUGE

FIGURE 18

SOUND-POWERED PHONES CONNECTED ALL PUMPROOMS

TABLE 6

MAXIMUM FLOWRATES - PIER 4 MULTI-SHIP TESTS

Ships Pumping	No of Pumps	Flowrate (GPM) Run #1	#2	#3	#4	Total Flowrate (GPM) Run #1	#2	#3	#4
Series A									
ROANOKE Fwd	2	860	850	850					
Midships	2	690	660	680					
Aft	2	640	660	640		2190	2170	2170	
Series B									
HULL & STEIN Aft	1	590	560	520	520				
HULL & STEIN Fwd	1	650	550	540	560				
JOUETT Aft; ENGLAND Fwd	1	400	540	590	600				
JOUETT Fwd; ENGLAND Aft	1	710	980	980	980	2350	2630	2630	2660
Series C									
HULL & STEIN Aft	2	840	680						
HULL & STEIN Fwd	2	820	640						
JOUETT Aft; ENGLAND Fwd	2	1050	750						
JOUETT Fwd; ENGLAND Aft	2	820	1130			3530	3200		
Series D									
HULL & STEIN Aft	1	610	580						
HULL & STEIN Fwd	1	660	540						
JOUETT Aft; ENGLAND Fwd	1	800	600						
JOUETT Fwd; ENGLAND Aft	1	700	980						
ROANOKE (All Pumprooms)	2	2170	2170			4940	4870		
Series E									
HULL & STEIN Aft	2	760	620						
HULL & STEIN Fwd	2	850	660						
JOUETT Aft; ENGLAND Fwd	2	1060	820						
JOUETT Fwd; ENGLAND Aft	2	860	1140						
ROANOKE (All Pumprooms	2	2170	2170			5700	5410		

For all tests, the flowrate entering the pier wetwell was greatly reduced due to the large diameter pier piping. The flowrate into the wetwell was measured for at least 720 seconds between each pump run to establish a maximum and average flowrate (Figures 19-23).

Tests were also conducted to determine if choking of the flowrate into the pier risers occurred with different combinations of pumps. Tests were conducted using 1, 2 and 4 pump combinations of ships on opposite pier risers. Flowrates from this series are presented in Table 7.

Backflow tests were conducted with check valves open on ships across the pier to see if backflow was noticed.

Observations

1. The gravity pier sewer was able to accept the maximum flowrate from 22 CHT discharge pumps all pumping simultaneously with no difficulty.

2. No choking of shipboard discharge flowrate was noted due to pier piping for any combination of pumps.

3. No cross pier backflow was observed through open pier risers or into ships across the pier.

4. Pressures at pier risers ranged from 0 to 0.5 psi during ship pumping.

5. Ship flowrates measured at the pier risers were reduced significantly upon entering the wetwell due to the capacity of the pier piping system to temporarily store the discharge in the piping between the riser and the wetwell. Flow into the wetwell ceased approximately 700 seconds after ship pumps were stopped (Figure 24).

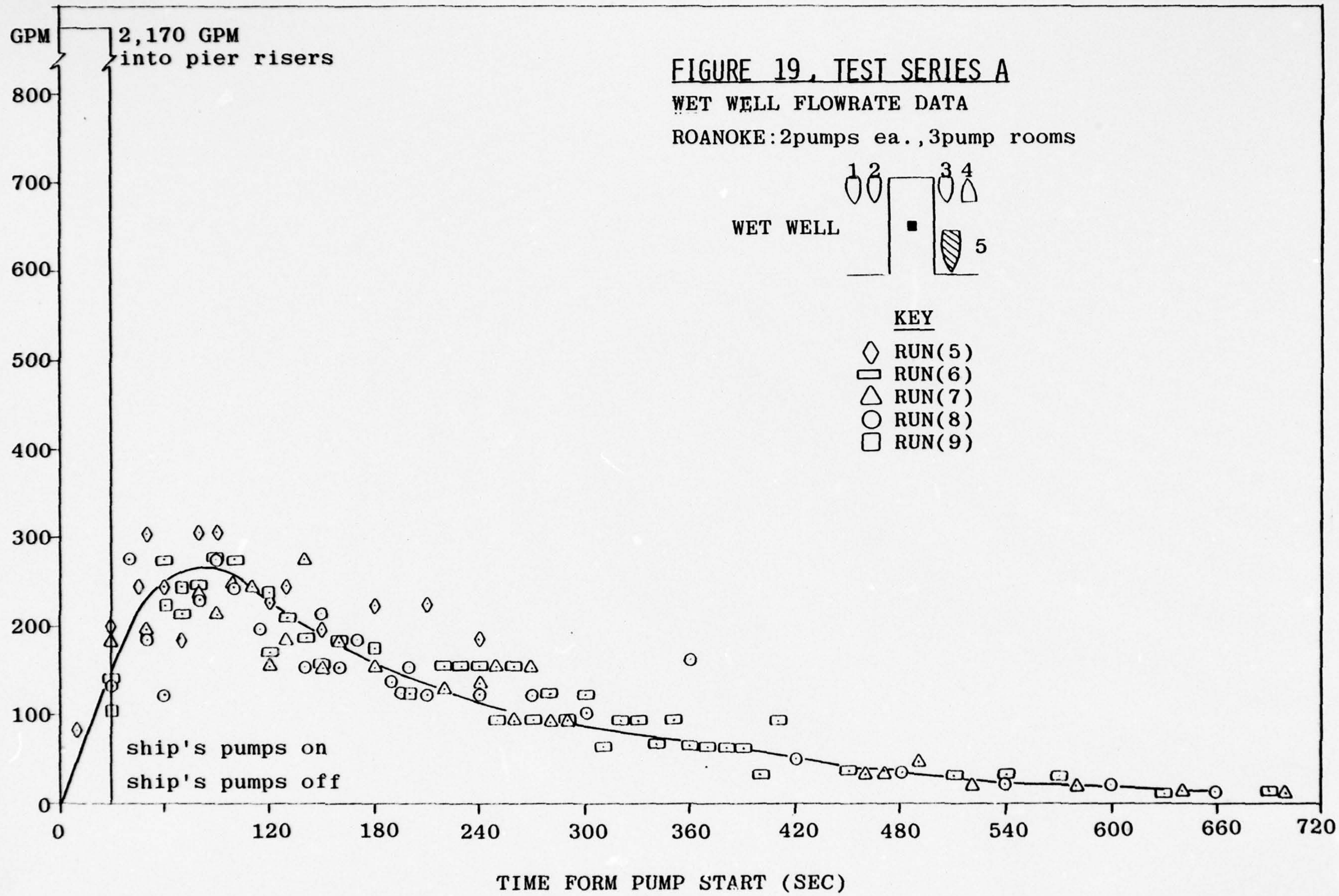


FIGURE 19, TEST SERIES A

WET WELL FLOWRATE DATA

ROANOKE:2pumps ea.,3pump rooms

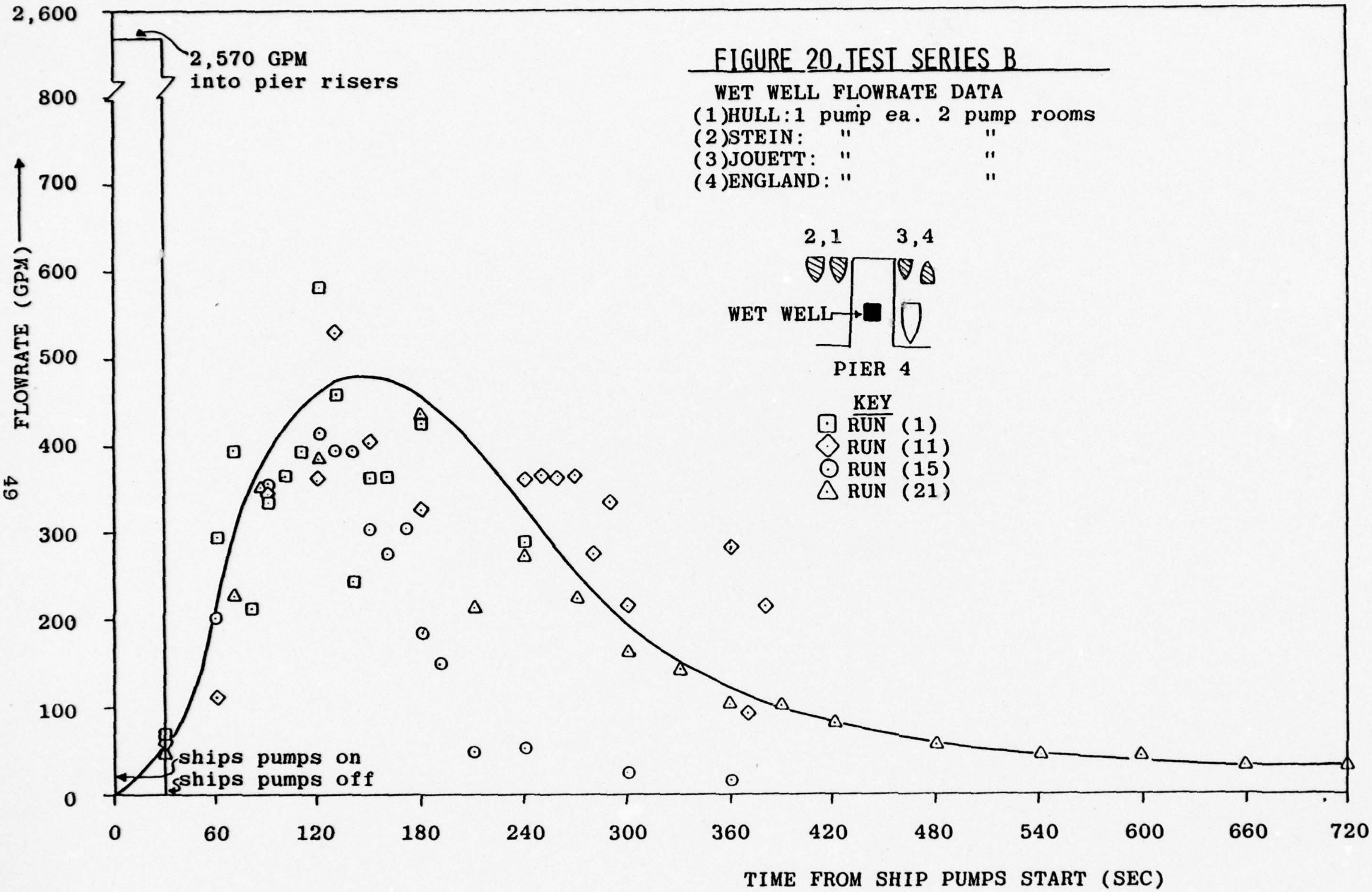


FIGURE 20, TEST SERIES B

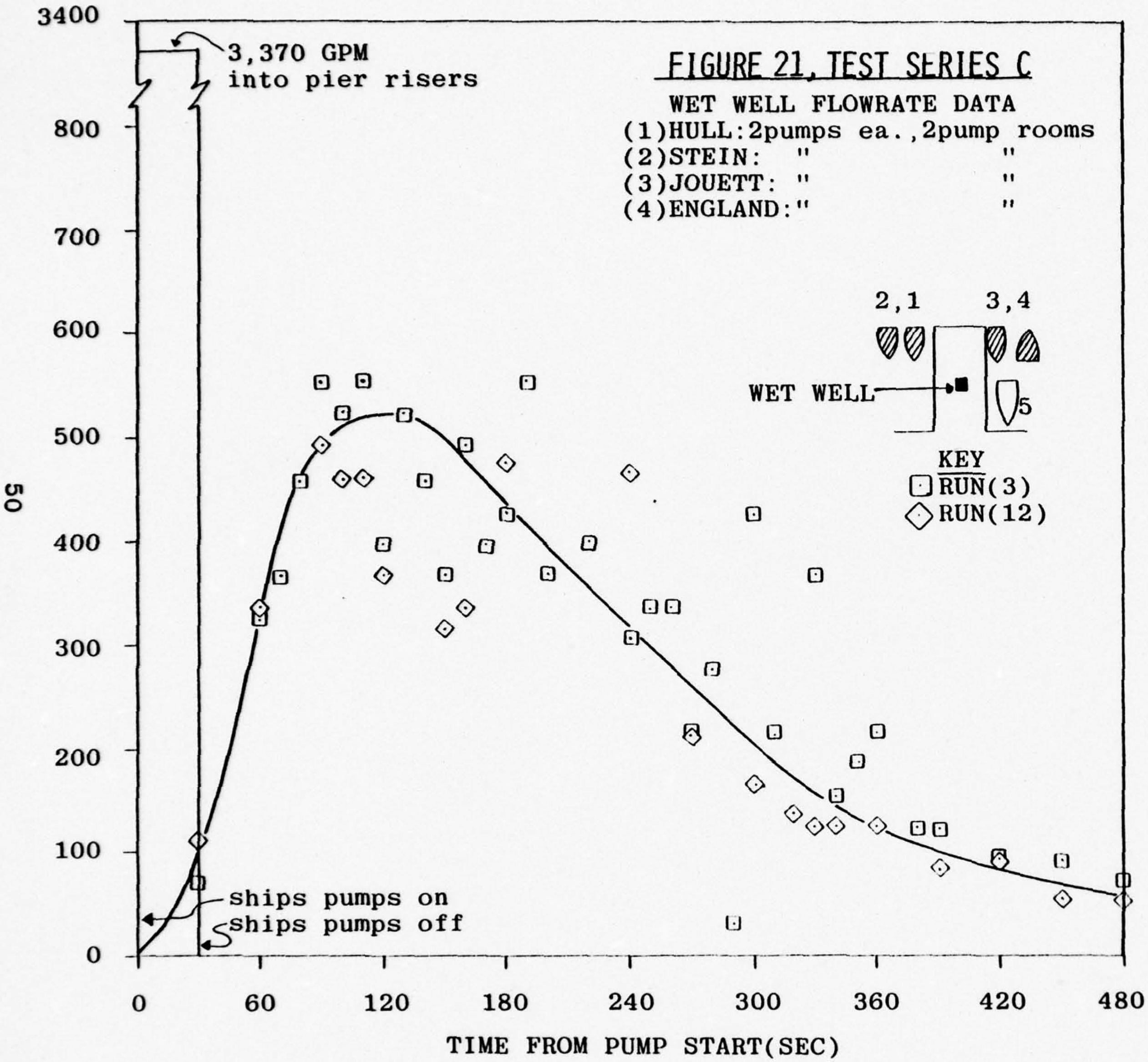


FIGURE 21, TEST SERIES C

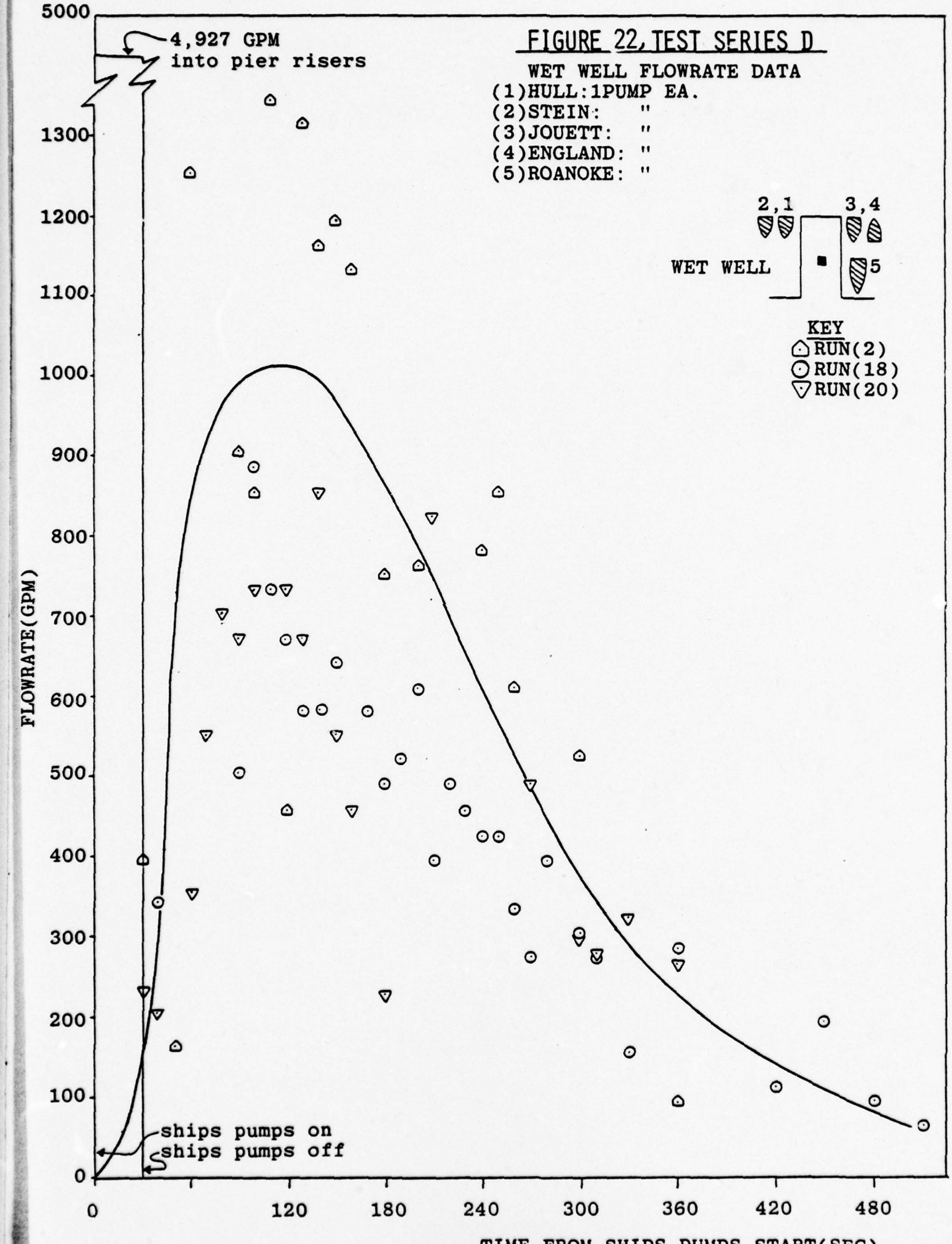


FIGURE 22, TEST SERIES D
WET WELL FLOWRATE DATA
(1)HULL:1PUMP EA.
(2)STEIN: "
(3)JOUETT: "
(4)ENGLAND: "
(5)ROANOKE: "
2,1
3,4
WET WELL
5
KEY
RUN(2)
RUN(18)
RUN(20)
4,927 GPM
into pier risers
ships pumps on
ships pumps off
FLOWRATE(GPM)
5000
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
120
180
240
300
360
420
480
TIME FROM SHIPS PUMPS START(SEC)

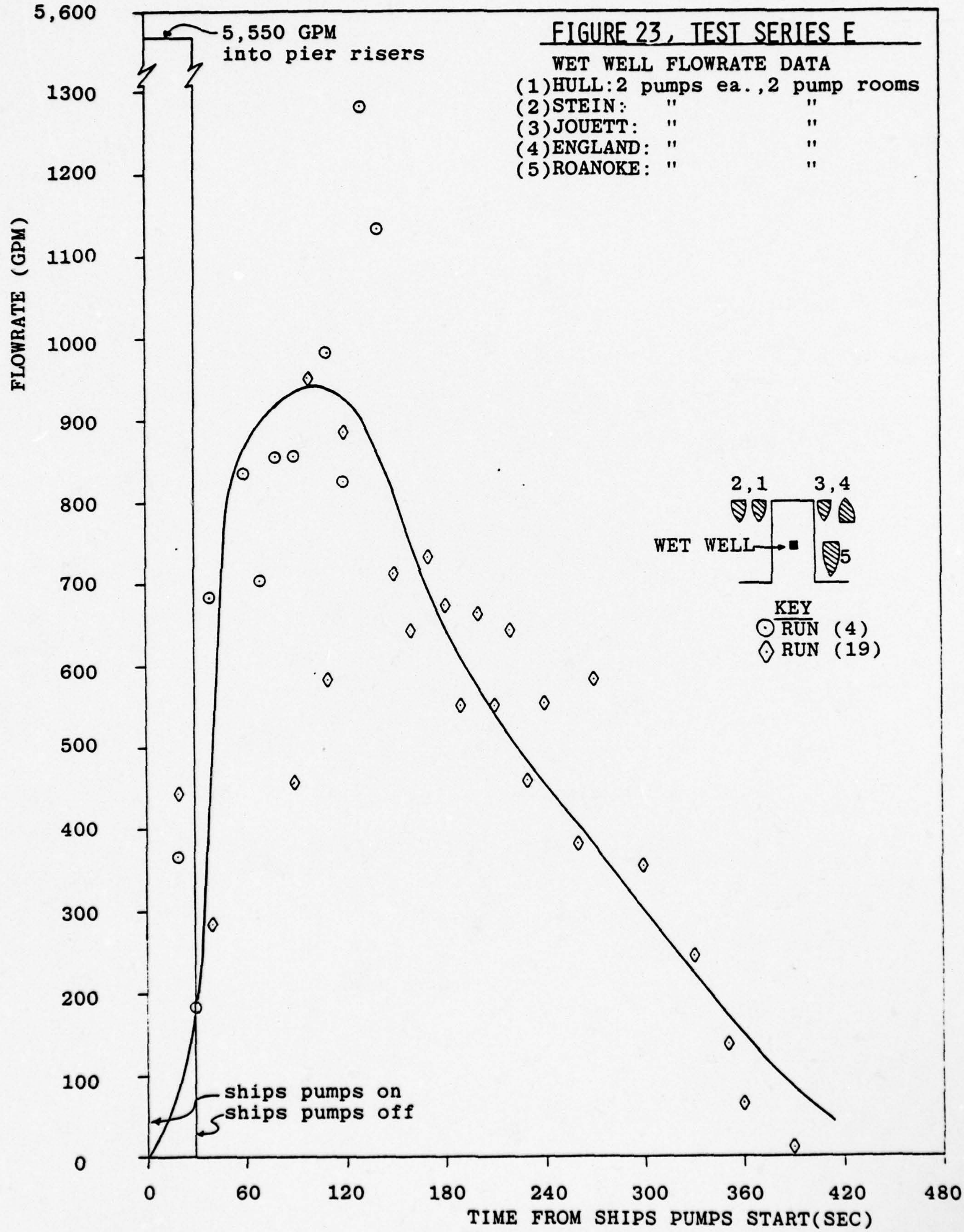


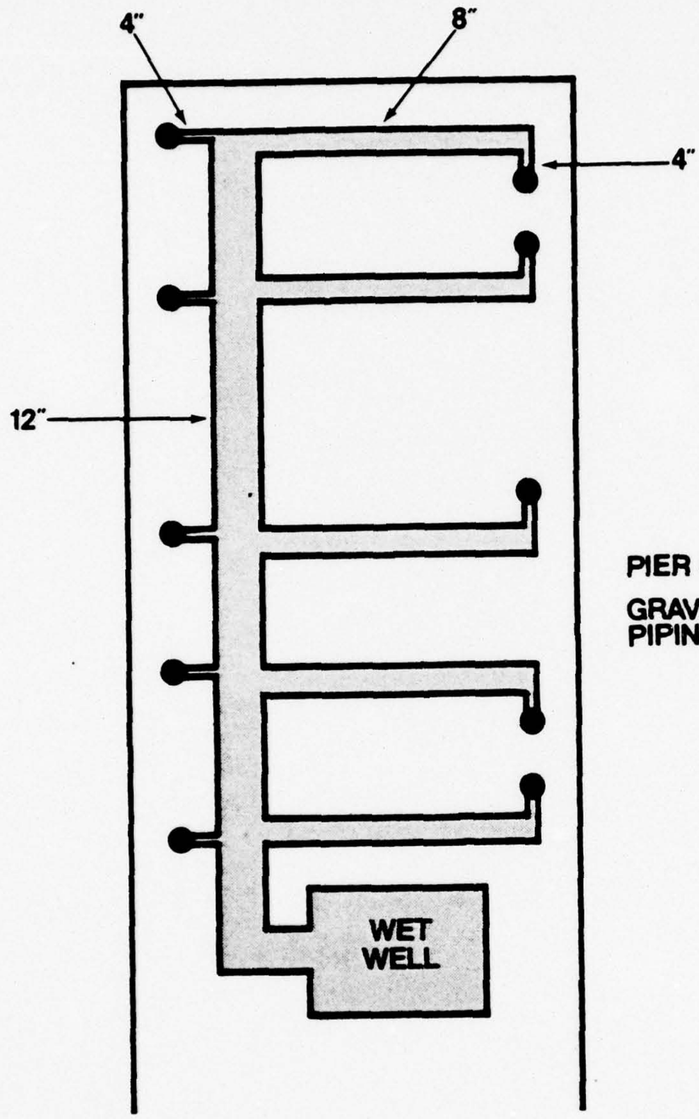
FIGURE 23, TEST SERIES E
WET WELL FLOWRATE DATA
(1)HULL:2 pumps ea.,2 pump rooms
(2)STEIN: " "
(3)JOUETT: " "
(4)ENGLAND: " "
(5)ROANOKE: " "
5,550 GPM into pier risers
ships pumps on
ships pumps off
2,1
3,4
WET WELL
5
KEY
RUN (4)
RUN (19)
FLOWRATE (GPM)
5,600
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
60
120
180
240
300
360
420
480
TIME FROM SHIPS PUMPS START(SEC)

TABLE 7

CHOKING EFFECTS - PIER 4 MULTI-SHIP TESTS

Run No.	Ships Pumping	No. of Pumps	Flowrate (GPM)
1	HULL & STEIN Aft	2	680
	HULL & STEIN Fwd	2	640
	JOUETT Aft; ENGLAND Fwd	2	750
	JOUETT Fwd; ENGLAND Aft	2	1130
2	JOUETT Aft; ENGLAND Fwd	2	750
3	JOUETT Fwd; ENGLAND Aft	2	1110
4	JOUETT Aft; ENGLAND Fwd	2	740
	JOUETT Fwd; ENGLAND Aft	2	1100

FIGURE 24



PIER 4

GRAVITY SYSTEM PIPING LAYOUT

4.2 Pressure Manifold Pier Tests (Pier 8)

Pressure pier tests were conducted with the USS OGDEN at Pier 8, San Diego Naval Station. Pier 8 was selected for this test because its sewer piping most closely resembles the standard pressure manifold sewer design described in the NAVFAC design manual DM-25. The tests were conducted to determine:

1. The maximum flowrate that could be developed in a 4 inch pier pressure line.

2. The minimum flow needed to produce backflow in an open pier riser in the manifold.

3. The amount of choking of flowrate caused by the pressure manifold.

4. The overall response of the pier piping, manifold and gravity line, to ship discharge.

The testing schematic is shown in Figure 25 and the underpier piping schematic is shown in Figure 26. For the tests the CHT discharge hose from the OGDEN was connected to 1 of 2 pier risers for each test situation. All CHT pumprooms discharge through a common hose on the OGDEN.

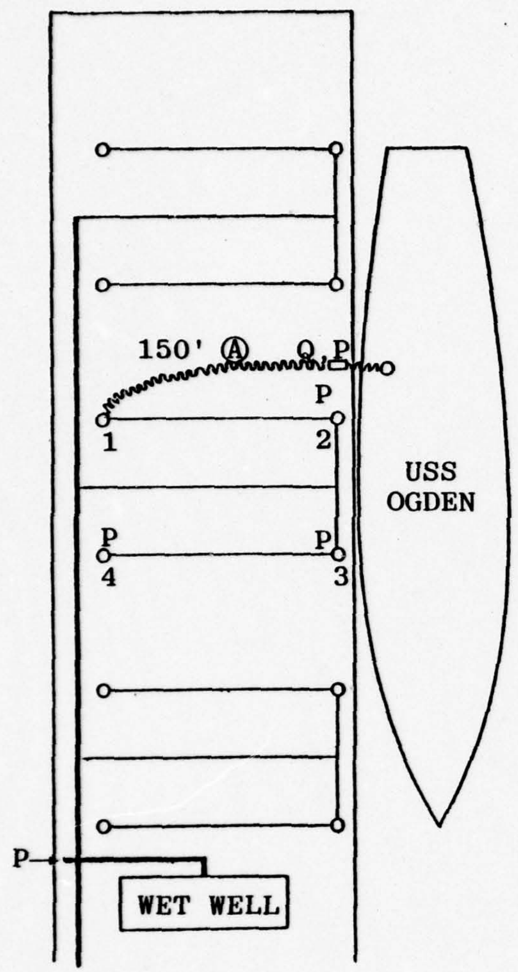
Four pumps were activated on the OGDEN and when backflow occurred in an open riser the valve was closed and a pressure reading taken.

The flowrate causing this backflow was measured. The tests were repeated at all available risers in the manifold. Results of the maximum flow tests are shown in Table 8.

Tests were also conducted to determine the minimum flow in a 4 inch pressure riser which would produce backflow. Pumps were activated on the OGDEN as necessary until backflow was noted on an open riser. The flowrate from the OGDEN was measured for this minimum discharge rate. The results of these tests are shown in Table 9.

FIGURE 25

PIER 8 PRESSURE SEWER TESTS



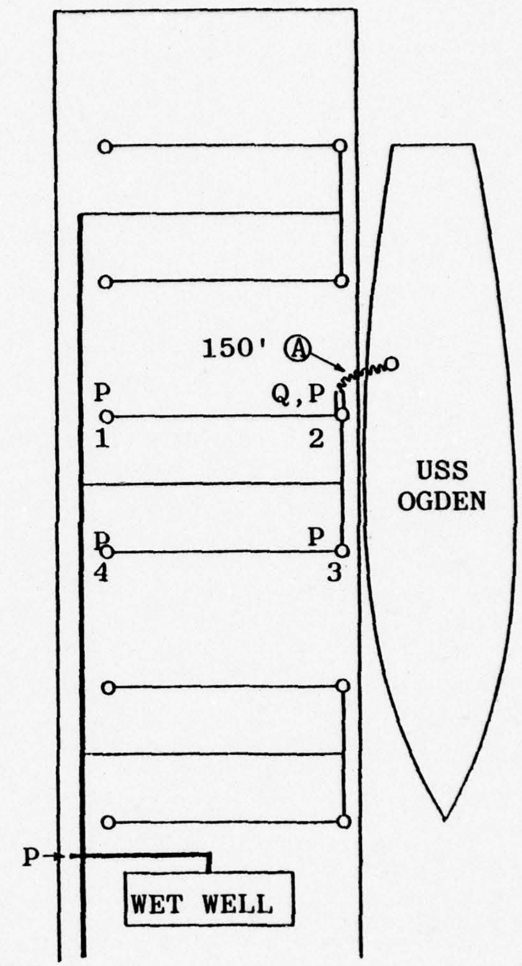
CONFIGURATION FOR MINIMUM,
MAXIMUM AND CHOKING FLOW TESTS

Q=FLOW RATE

P=PRESSURE

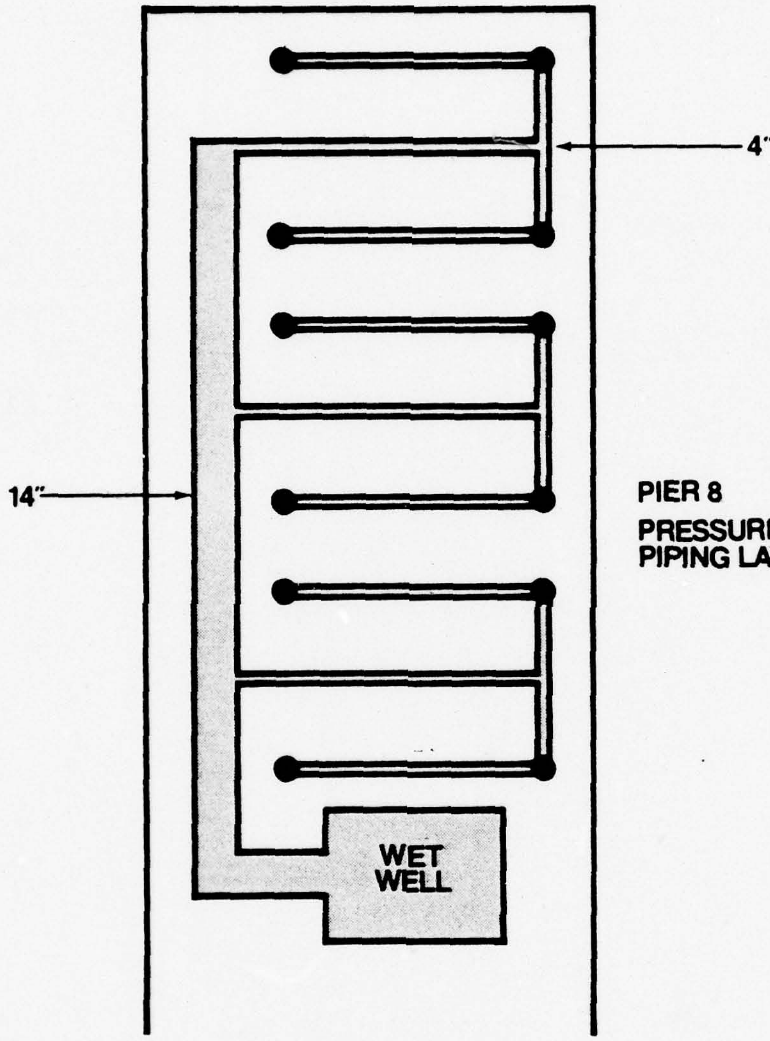
(A)=PLASTIC HOSE

o=PIER & DECK RISERS



CONFIGURATION FOR MINIMUM FLOW,
MAXIMUM FLOW, CHOKING, SEWER RESPONSE
AND GRAVITY MAIN PRESSURIZATION TESTS

FIGURE 26



PIER 8
PRESSURE SYSTEM
PIPING LAYOUT

TABLE 8

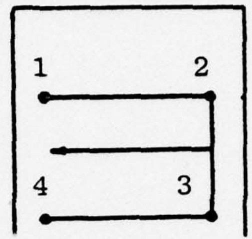
MAXIMUM FLOWRATES - PIER 8

Hose Length - 150 ft.

Hose Type - Plastic

Number of Pumps - 4

Riser Locations

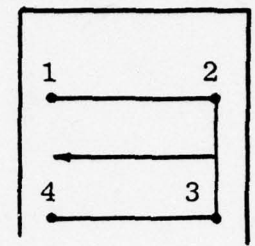


Ship Discharge Pier Riser No.	Ship Flowrate GPM	Pressure At Pier Riser (psi)	Open Pier Riser No.	Pressure At Open Pier Riser (psi)
2	750	12	1	9
2	750	12	3	2
2	760	11.5	4	2
1	650	15	2	8.5
1	660	15	2	2
1	690	13	2	1.5

TABLE 9

MINIMUM BACKFLOW RATES - PIER 8

Riser Locations



	Ship Discharge Riser Location			
	Riser 1		Riser 2	
Open Pier Riser Location	Flowrate GPM	Number of Pumps	Flowrate GPM	Number of Pumps
1			400	1
2	410	1		
3	640	2	650	2
4	640	2	650	2

Choking tests for the pressure pier manifold were conducted by comparing flowrates for 1, 2 and 4 pumps operating or pumping into an open discharge with flowrates measured by pumping into the pier manifold sewer system. The results of these tests are shown in Table 10.

The response of Pier 8 sewer piping (Figures 27 and 28) was tested by operating 1, 2 and 4 pumps aboard the OGDEN and measuring the level rise rate in the pier wetwell. A pumping period of 30 seconds was used for these tests.

An additional test to measure normal CHT pumping time was conducted. Pumping time for 30% pumpdown for each of the CHT tanks in the OGDEN was measured. The results are shown in Figures 29 and 30.

Observations

1. Backflow occurred in all open inactive risers that were connected in the 4 inch pressure manifold. The adjacent open riser (Figure 25 riser 1) before the main drain line lateral would backflow when ship CHT flowrate was approximately 400 gpm. The 2 risers after the main lateral drain line would backflow when ship CHT flowrate was approximately 650 gpm (Figures 31 and 32).

2. Choking of flows in the 4 inch pressurized manifold reduced ship discharge flowrates from between 6% and 16% for various pump combinations as shown in Table 10.

3. The 14 inch gravity main on Pier 8 was not pressurized from ship pumping and appeared to handle the 750 gpm flowrate with no difficulty.

4. Flowrates from the ship were reduced substantially as the flow drained into the wetwell. Peak flowrates measured at the wetwell were only 5% to 7% of the flowrate observed at the pier riser.

5. A vacuum of 7 inches of mercury was measured in the gravity drain line while flow was draining to the wetwell.

TABLE 10

CHOKING EFFECTS - PIER 8

	Open Discharge	Pumping Into Riser #1 (see Figure 26)		Pumping Into Riser #2 (see Figure 26)	
Number of Pumps	Flowrate GPM	Flowrate GPM	% Choke	Flowrate GPM	% Choke
1	540	500	7	500	7
2	710	640	10	650	8
4	800	675	16	750	6

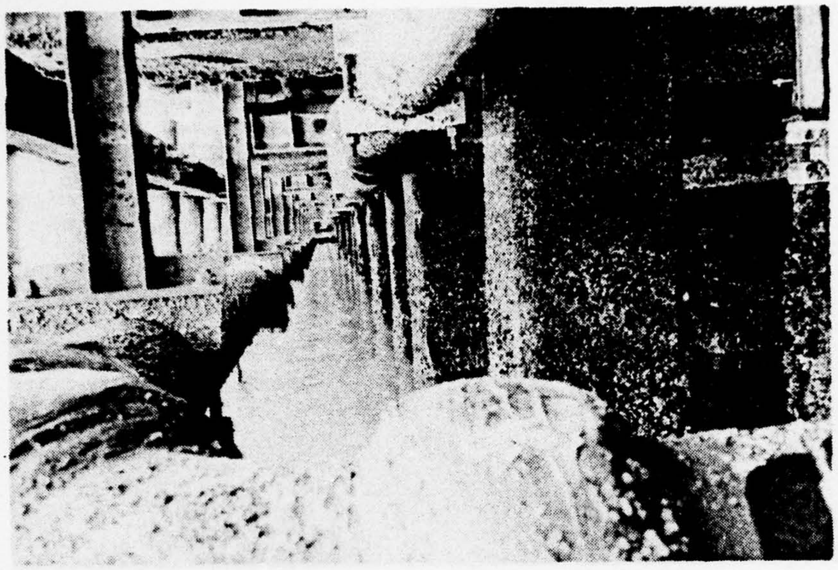


FIGURE 27
UNDERPIER SEWER PIPING

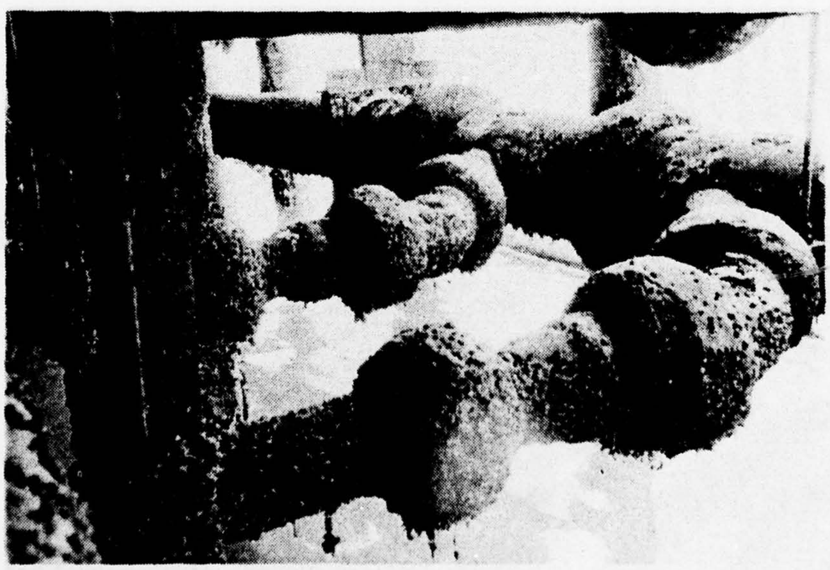


FIGURE 28
4 INCH MANIFOLD JOINING 14 INCH MAIN

FIGURE 29

WET WELL FLOW RATE DATA

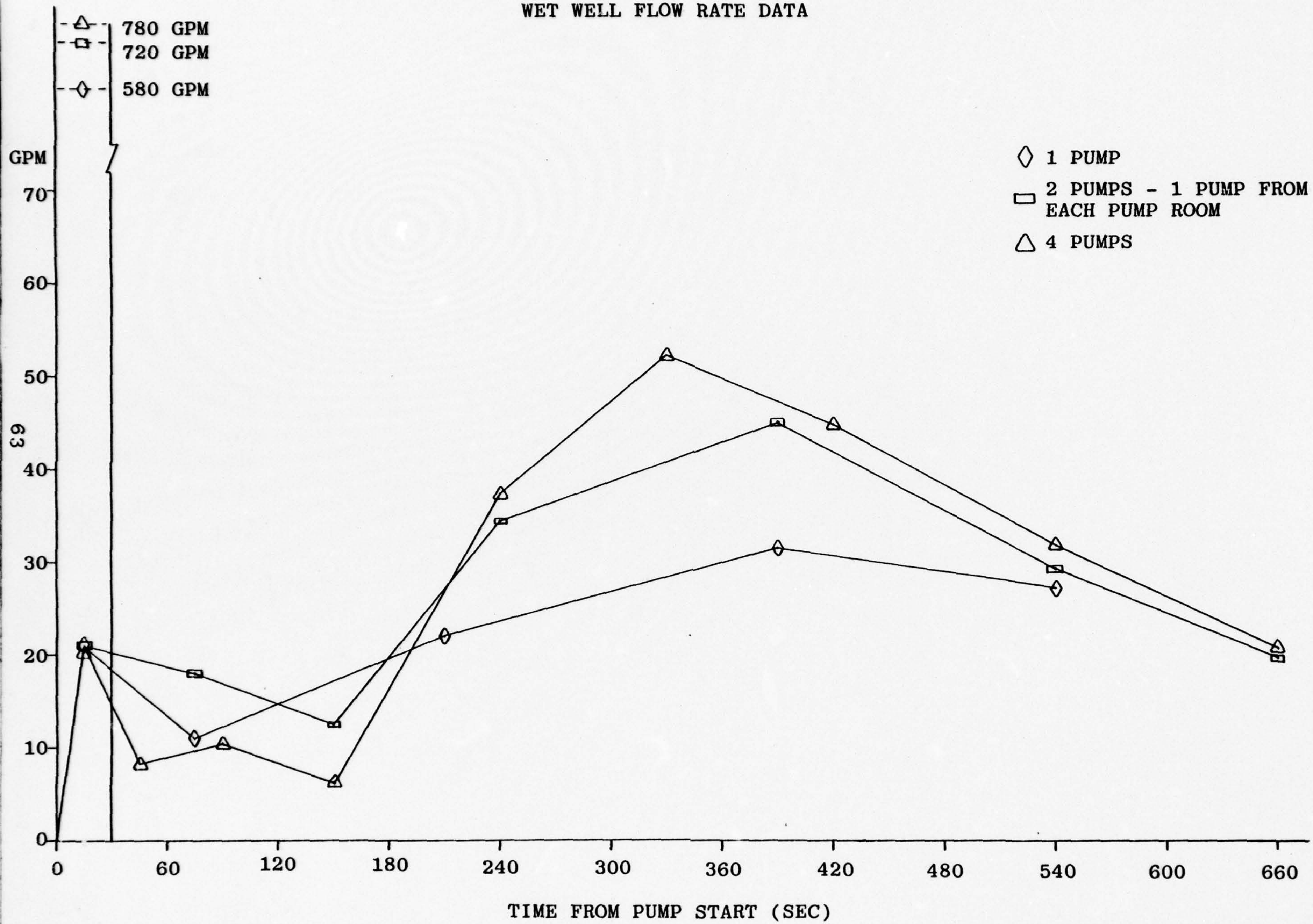
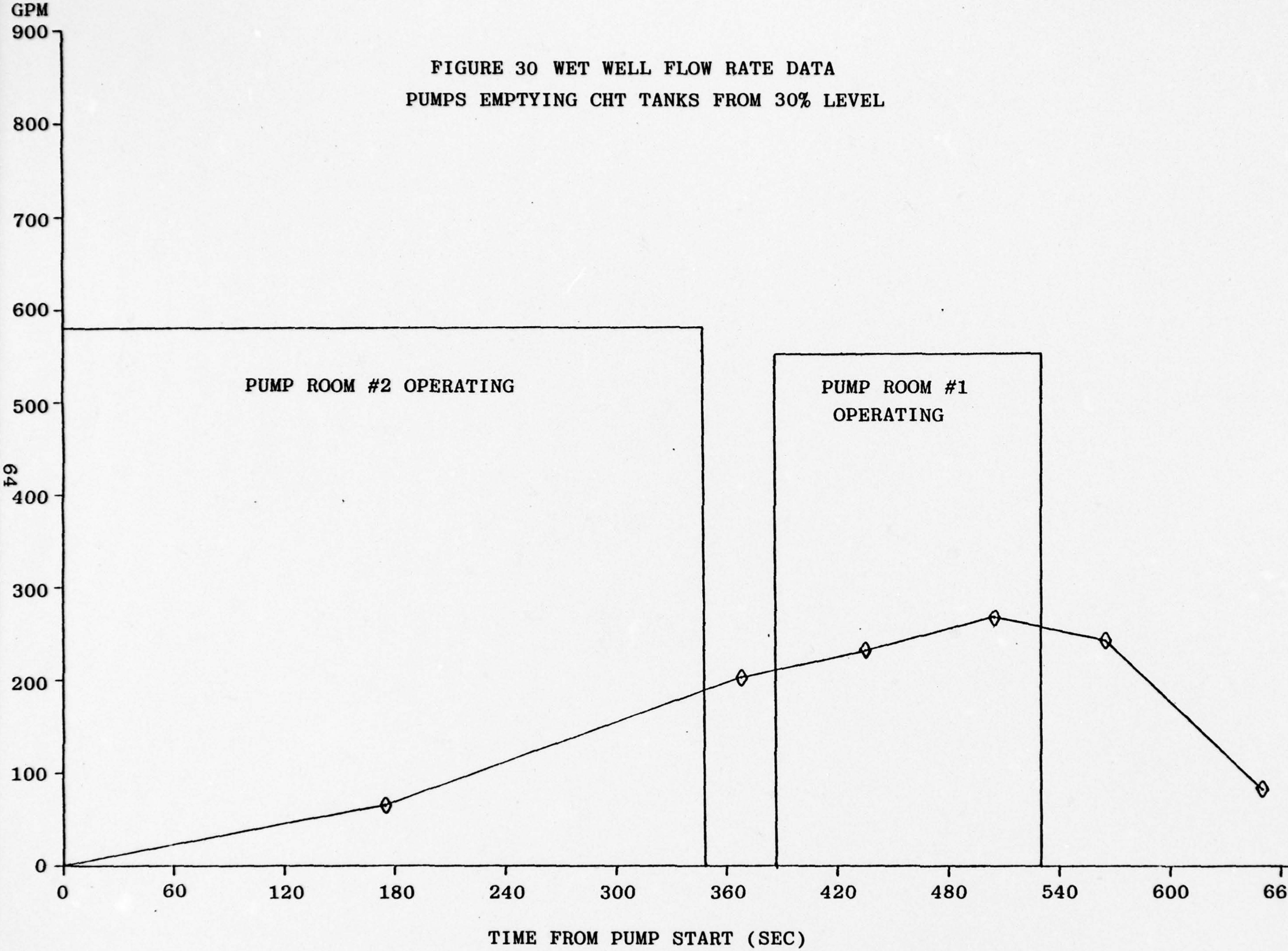


FIGURE 30 WET WELL FLOW RATE DATA

PUMPS EMPTYING CHT TANKS FROM 30% LEVEL



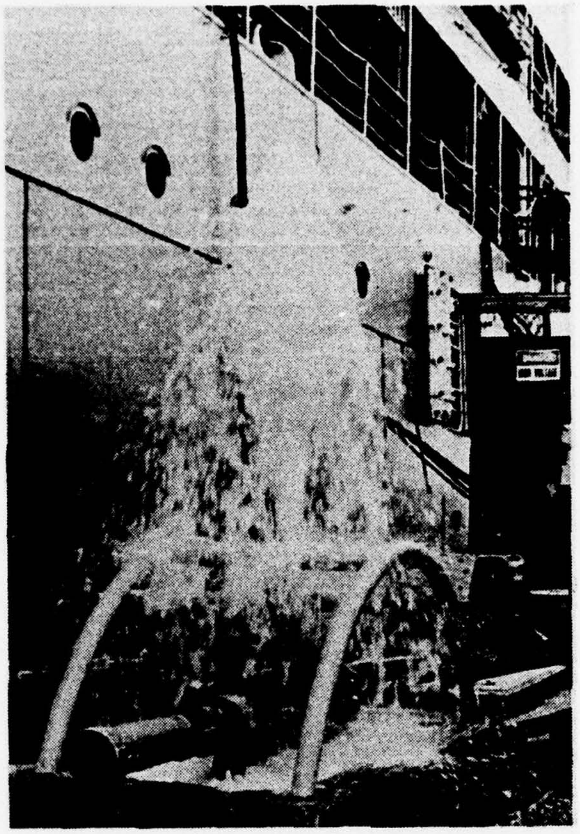


FIGURE 31

ADJACENT PIER RISER BACKFLOW (TABLE 8 - OPEN RISER NO. 1)

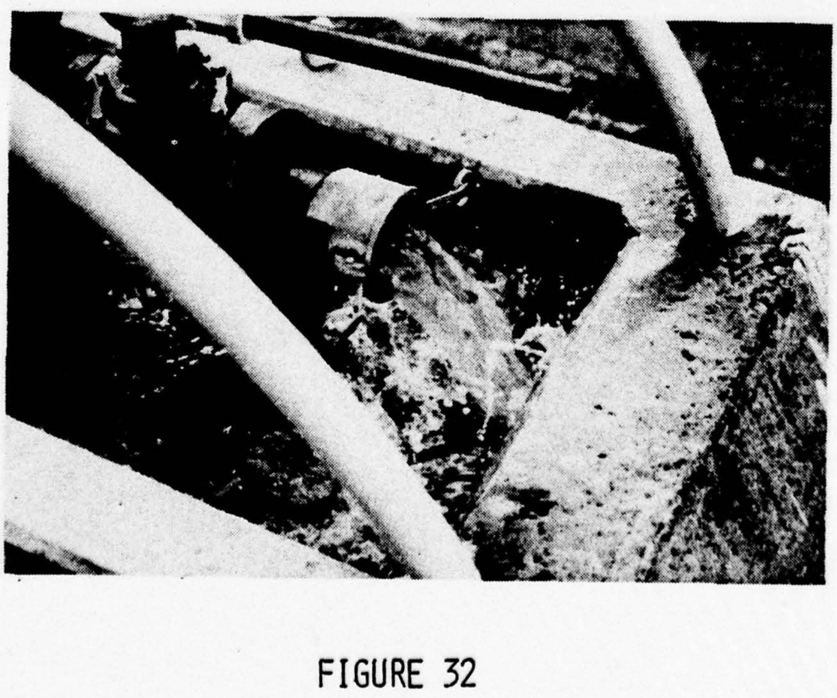


FIGURE 32

BACKFLOW FROM LAST MANIFOLD PIER RISER (TABLE 8 - OPEN RISER NO. 4)

4.3 Test Conclusions

Gravity Pier 4

1. Pressures at pier sewer risers on gravity piers are not expected to exceed 1.0 psi under normal operating conditions.

2. The gravity pier was capable of handling over 5700 gpm of ship discharge from 11 pumprooms and 22 pumps simultaneously with no adverse effects. Due to the short pumpdown times in normal CHT operation, and the capacity of gravity piers, no problems are expected if the pier is fully loaded with CHT equipped ships.

3. Flow from individual ships will not be choked by pier piping on gravity piers under normal operating conditions.

Pressure Pier 8

1. Backflow from open pier risers on pressure pier manifolds will occur under most pumping conditions.

2. The 4 inch diameter piping manifolds do not significantly choke or reduce the flowrate from CHT ships.

3. The maximum pressure developed at a pier riser on a pressure manifold system is approximately 12 psi.

4. Great care is required when connecting or disconnecting ships to pressure pier sewer systems. Hoses that have been flushed with salt water in preparing for disconnect may be recontaminated through backflow from other CHT systems on the same manifold.

5. Maximum flowrate expected from an LPD class ship with a single discharge connection and 4 pumps pumping is approximately 800 gpm.

5. HOSE HANDLING

Hose handling tests using a destroyer tender in a nest of destroyers were conducted to investigate problem areas associated with CHT hose connections. The ships used for these tests included the tender USS GOMPERS, USS JOHN PAUL JONES, and the USS ALBERT DAVID.

Hose handling focused on the areas of hose transport from pierside to ships outboard of the tender and disconnection procedures to eliminate sewage spills. Non-collapsible 4 inch hose was used for these tests. Many of the procedures documented for connection and disconnection apply to all classes of ships regardless of their use with a tender.

Two alternatives were considered for hose transport: cargo transfer cranes on the tender and manual handling by deck crews. Hose was delivered using San Diego Public Works Center powered hose reel (Figure 33). Observations were made and procedures documented of the time required to transfer hose and the number of men required in the handling crews.

In the crane tests, 150 feet of hose from the hose reel truck was coiled on the pier. All hose was gathered by nylon straps and lifted by the outboard 30 ton crane. The hose was lifted to the top of the tender deck and transferred to the outboard crane and lowered to the nearest destroyer (Figure 34).

The manual test consisted of unreeling 150 feet of hose from the PWC hose reel up to the stern of the tender and passing it down manually to the stern of the inboard destroyer (Figure 35).

Two alternatives were tested for standard procedures in disconnection and draining transfer hose. These alternatives were gravity draining of a disconnected hose and a procedure using a low pressure air blowdown fitting developed by the San Diego Public Works. Both procedures were used after discharge hoses were filled in the normal manner by CHT discharge pumps.

Typical gravity procedures consisted of breaking the hose connection at the deck riser and lifting low sections of the hose

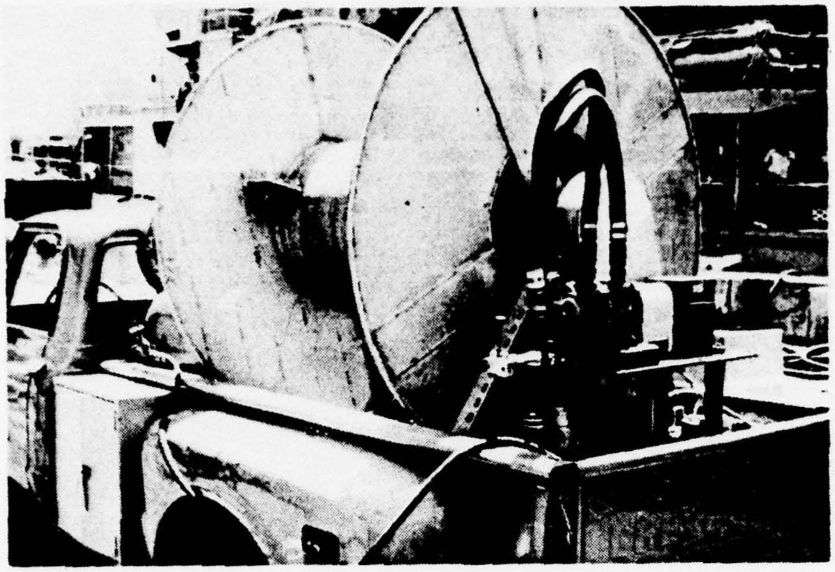


FIGURE 33

PWC HOSE REEL

FIGURE 34

HOSE TRANSFER BY TENDER CRANE

higher than the riser where the hose was connected. In this way the water in the hose would drain by gravity to the open riser.

Low pressure air blowdown of the sewage hose is possible through a standard air connection fitting attached at the deck riser. The air valve at the deck riser is connected to ships service low pressure air. The air valve is opened and the hose blown empty (Figure 36).

After hose draining with each procedure, the highest end of the hose was disconnected and the hose drained of residual water. The amount of collected fluid left in the hose was compared.

5.1 Observations of Hose Handling Procedures

1. Hose transport using the tender's crane required approximately 20 minutes to complete. This operation required 2 PWC workers and 1 crew member from the GOMPERS at the pier. One crane operator and 1 line handler were required on the deck of the GOMPERS, and 2 men were needed to receive the hose on the deck of the JOHN PAUL JONES.

2. Personnel involved in the operation of cranes aboard the GOMPERS stated that they preferred to handle the hose in the most compact form possible such as small coils or coils loaded on pallets. The method used in this test was the best compromise between the requirements of the tender and the capabilities of the PWC powered hose reel.

3. Hose transport using manual labor required approximately 20 minutes to complete. The operation required 2 PWC personnel and 3 crew members of the GOMPERS on the pier. An additional 5 crew members were required to handle the sewage hose to the stern of the GOMPERS, and 4 crew members of the JOHN PAUL JONES were needed to coil the hose on the destroyer.

4. A 6 man crew from the JOHN PAUL JONES, the inboard destroyer, was required to carry hose to the ship's deck risers for connection.

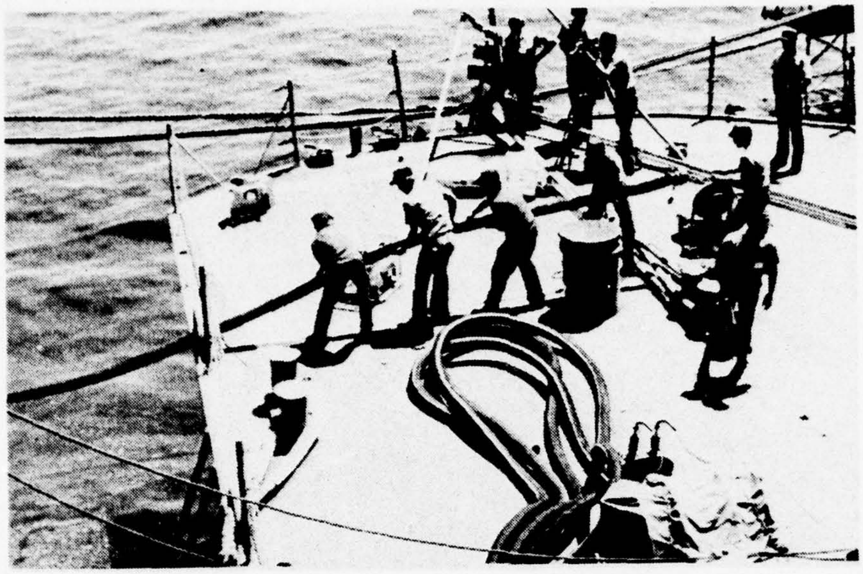


FIGURE 35

HOSE PULLED TO DECK OF INBOARD DESTROYER JOHN PAUL JONES

FIGURE 36

AIR BLOWDOWN FITTING

5.2 Observations of Disconnection and Drainage Procedures

1. Hose draining by simple disconnection and draining was not very successful. After 4 repetitions of lifting and draining low spots in the hose, the hose still contained 5 to 10 gallons of liquid.

2. Hose draining, after a salt water flush, using the low pressure air blowdown fitting (Figure 36) was successful. However, even with this method it is necessary to lift low spots to promote draining and flowing of the water out of the hose. When disconnected no water remained in the hose and the interior of the hose appeared to be dry.

3. Considerable salt water from sewage hoses was spilled when the hoses were disconnected from the aft mooring station of the GOMPERS.

4. During previous testing the flat rubber hose provided by the GOMPERS was restowed in the aft mooring station (Figure 37). Considerable residual water was spilled as the hose was disconnected and loaded onto the hose reel inside the mooring station. The mooring station compartment has no washdown facilities and does not allow for draining the hose of any residual water. In addition, the loose end of the hose is a hazard as additional sections are loaded on the reel by hand.

5.3 Test Conclusions

1. Hose handling for nests of ships does not present any significant handling problem. The connecting and disconnecting procedures for nested ships are presented in Appendix A. These procedures are based on those used during these field tests and represent a practical approach to standardized hose handling and sanitation procedures.

2. The transport of hose to nests of ships outboard a tender can be accomplished by either a tender's crane or manual labor.

The crane should be used if more than 150 feet of hose must be transported at one time.

3. All hoses should be capped before being transported to a pier in order to minimize sewage spills. Camlock caps and plugs, not plastic caps, should be used for hose ends. Plastic caps are easily knocked off the hose end while being handled.

4. Noncollapsible hose is much easier to rig aboard ships than collapsible hose (Figure 38). The care and rigging required to prevent collapsible hose from kinking offsets the advantage this hose may have while being carried about the piers. Collapsible hose also requires regular attention for changes in tide and other utilities.

5. The use of a low pressure air blowdown fitting to drain sewage hose prior to disconnect is a superior method of hose draining. The possibility of spill from such a hose is reduced and draining procedures are efficient and quick. The suggested configuration of a low pressure air blowdown fitting is shown in Figure 39.

6. Communication between CHT pumprooms and deck riser stations during connection and disconnection is essential to minimize the potential of sewage spills. Throughout this testing program it became clear that a key individual on each ship, such as a designated CHT officer, is necessary to coordinate activities and to insure that health and safety procedures are followed. While berthed in a nest the CHT officer on the inboard ship is best situated to maintain overall control during connection and disconnection.

7. While ships are connected in a nest, their CHT systems are highly dependent on one another. Inboard ships must insure that CHT lines do not become blocked or valves inadvertently changed that may cause the outboard ship's system to back up. Quarter deck watches on both ships must be able to communicate easily and clearly if a problem arises. Crews on inboard ships must be aware

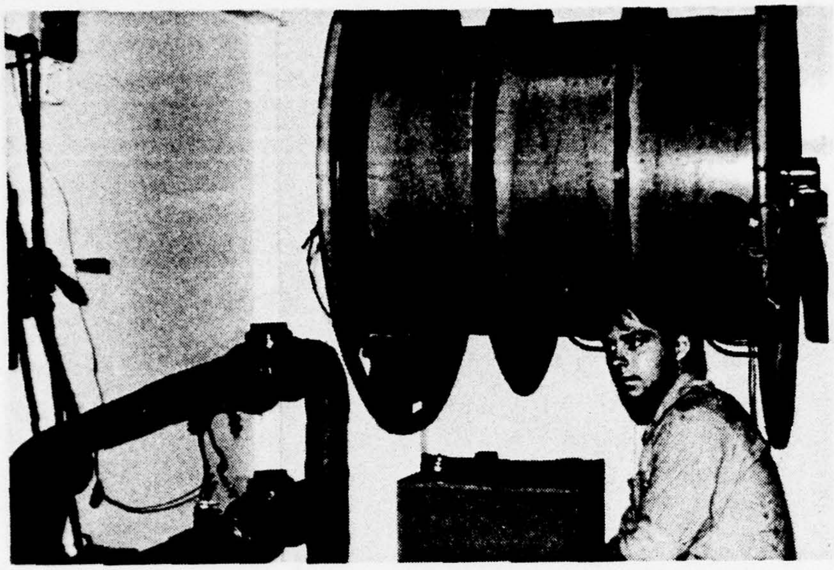


FIGURE 37
TENDER HOSE REEL

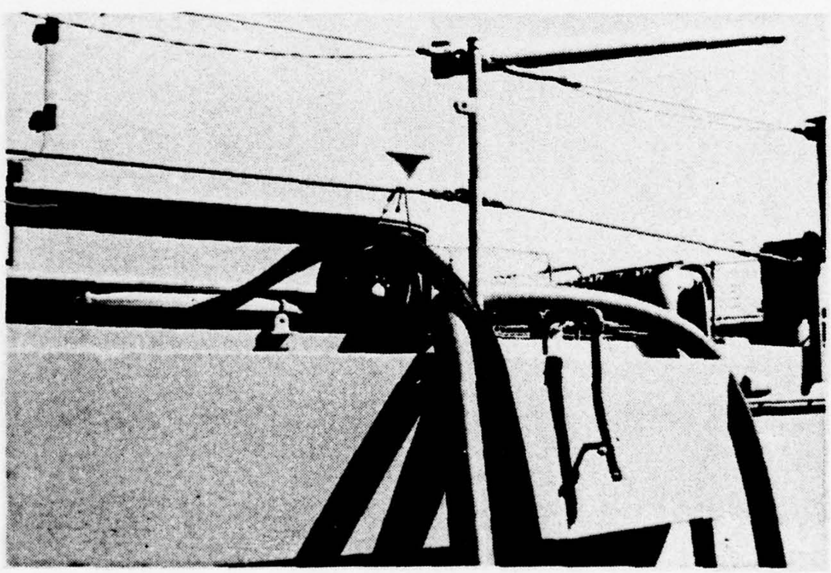
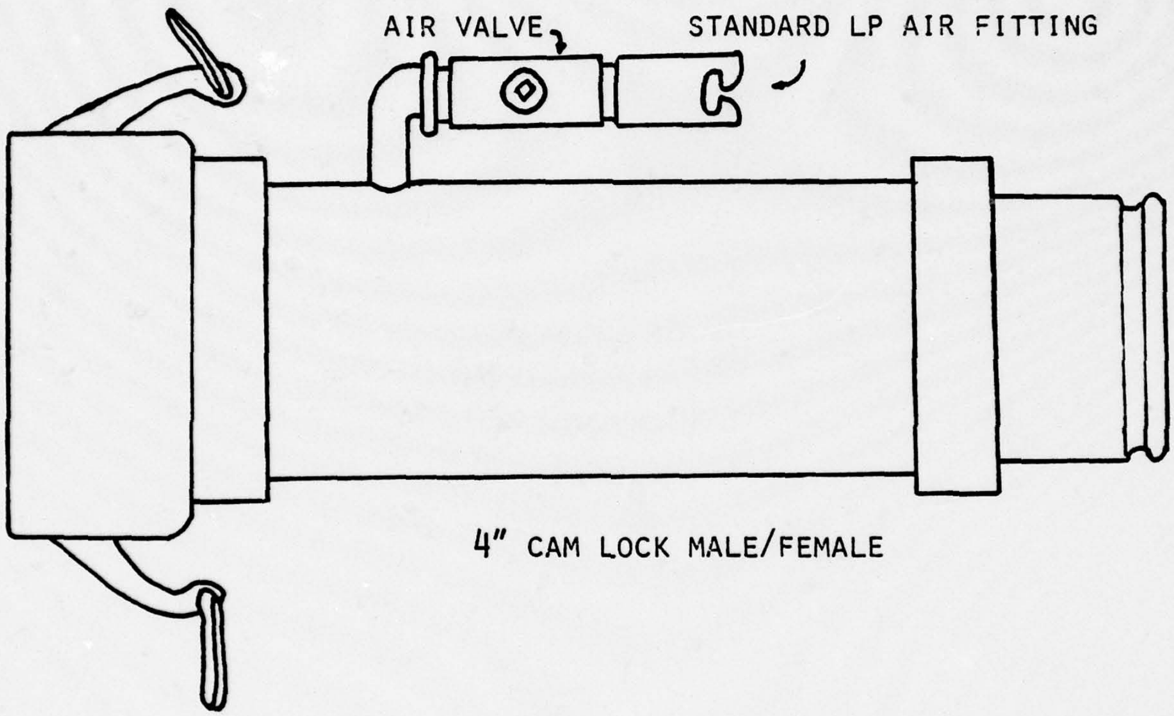


FIGURE 38
COLLAPSIBLE HOSE AND RIGID HOSE

FIGURE 39



SUGGESTED CONFIGURATION OF
LOW PRESSURE AIR BLOW DOWN FITTING

that their activities with the CHT system can affect other systems on outboard ships.

8. Special handling and rigging procedures must be developed for CHT connections between ships and AD-37 class tenders. Because CHT equipped mooring stations on the tenders are spaced too far apart, it is difficult to conveniently use both stations. Presently it is necessary to rig additional hose along the destroyer deck to complete CHT connections.

9. All hose fittings and related equipment should be the responsibility of shoreside personnel. Neither the ships nor tenders should be responsible for maintaining and storing sewage transfer equipment. This will insure that all hose and fittings are properly maintained and cleaned by the same activity.

6. CHT SEWAGE MONITORING TESTS

6. CHT SEWAGE MONITORING TESTS

Three separate monitoring tests of sewage generation rates were conducted on 2 ships. The rates represent combined black and gray water flows from a ship's CHT system. Flows were measured while each ship was pumping into the pierside sewer. In addition, generation rate data was obtained from one of these ships while at sea.

Tests were conducted on the USS ENGLAND from April 26 to April 29 for a total of 68 test hours. Tests were conducted on the USS HULL from July 14 to July 16 for 48 hours, and from July 16 to July 31 for 360 hours. During this time, the HULL was at sea for a total of 4 days.

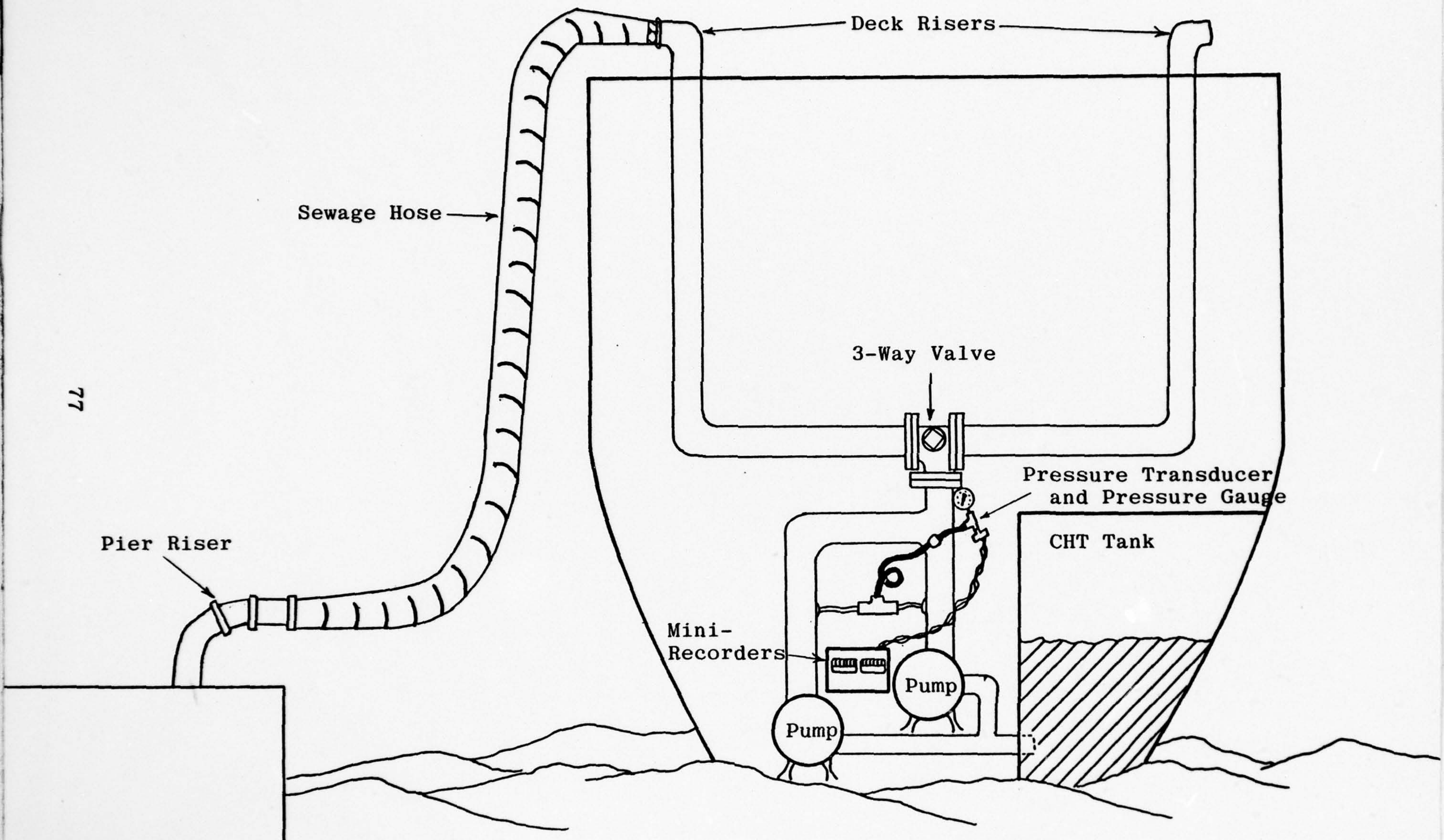
The sewage generation rate was determined by recording the time of CHT pump operation in each pumproom. The daily sewage generation rate was calculated from the time of the CHT pump activation and the pre-measured volume of each individual CHT tank between the 30% and 10% level sensors (Figures 40, 41).

Sewage generation rates and pump firing frequencies as a function of time for the ENGLAND are presented in Figures 42 and 43. Similar results for the HULL are presented in Figures 44 through 49. A summary of daily sewage generation rates for each CHT system aboard the ENGLAND and the HULL are presented in Tables 11 through 13.

The sewage monitoring data clearly shows a large difference between the sewage generated daily of these two ships. The ENGLAND, with a ship's complement of approximately 350 men, generated an average of 7,214 gallons of sewage per day (Table 11). The HULL, a smaller vessel with a complement of approximately 250 men, generated an average of 16,136 gallons of sewage per day (Table 13).

The large differences in sewage generation rates between these 2 ships points out that sewage generated is not a clear function of population but is easily overwhelmed by water use habits on a particular ship. It was noted that on the HULL urinal flush valves were set for continuous flush to keep collection lines from clogging.

FIGURE 40 Monitoring Set-Up (Single Ship)



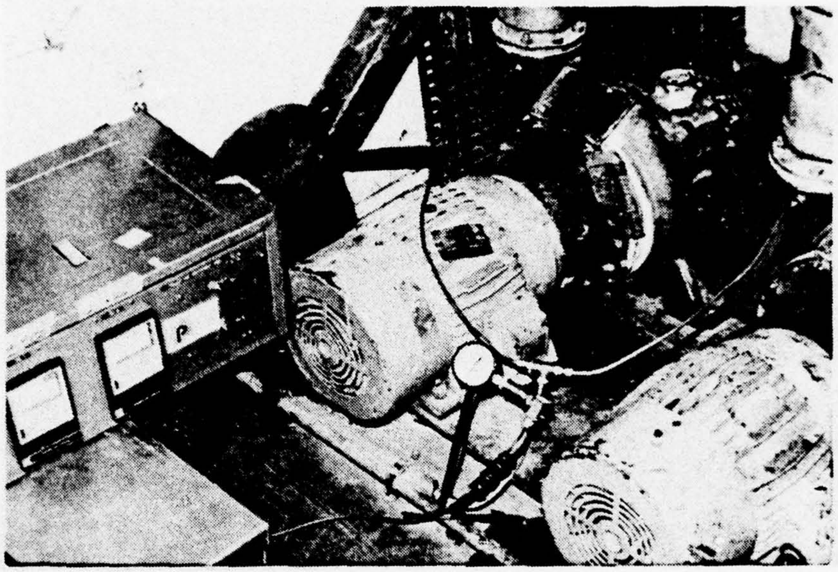
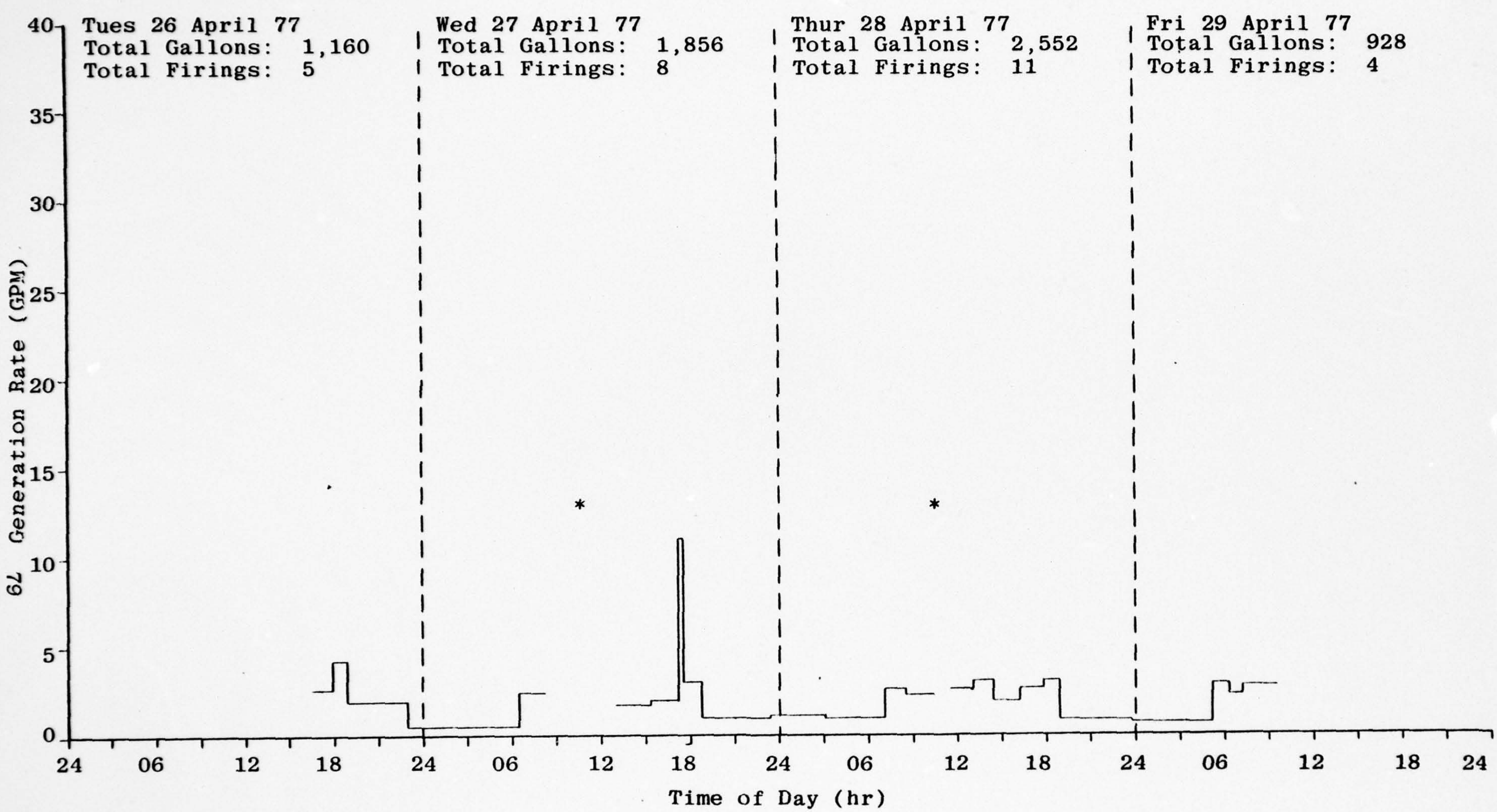


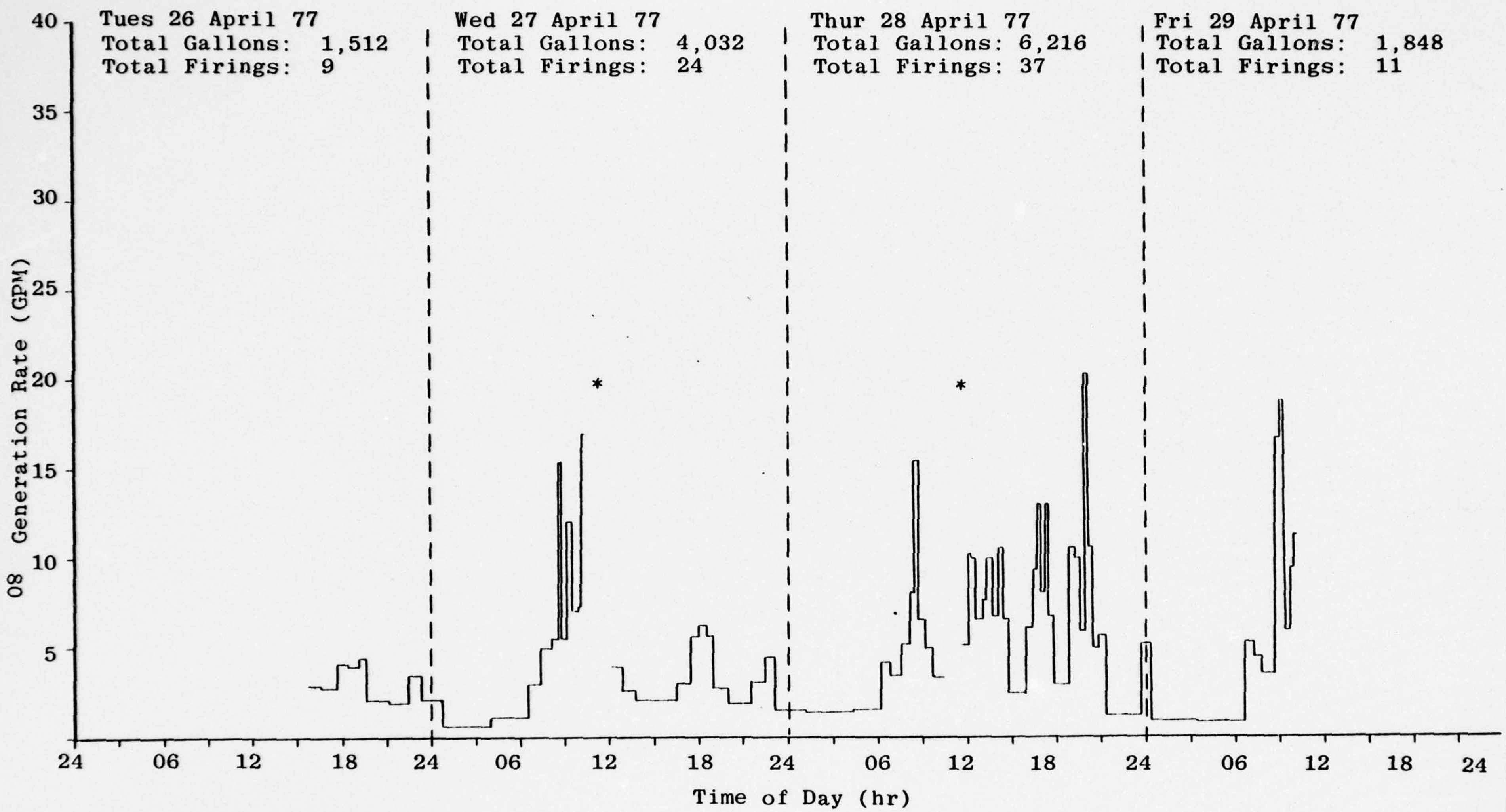
FIGURE 41
PRESSURE TRANSDUCER AND RECORDER

FIGURE 42 Generation Rate vs Time of Day USS ENGLAND Fwd Pump Room



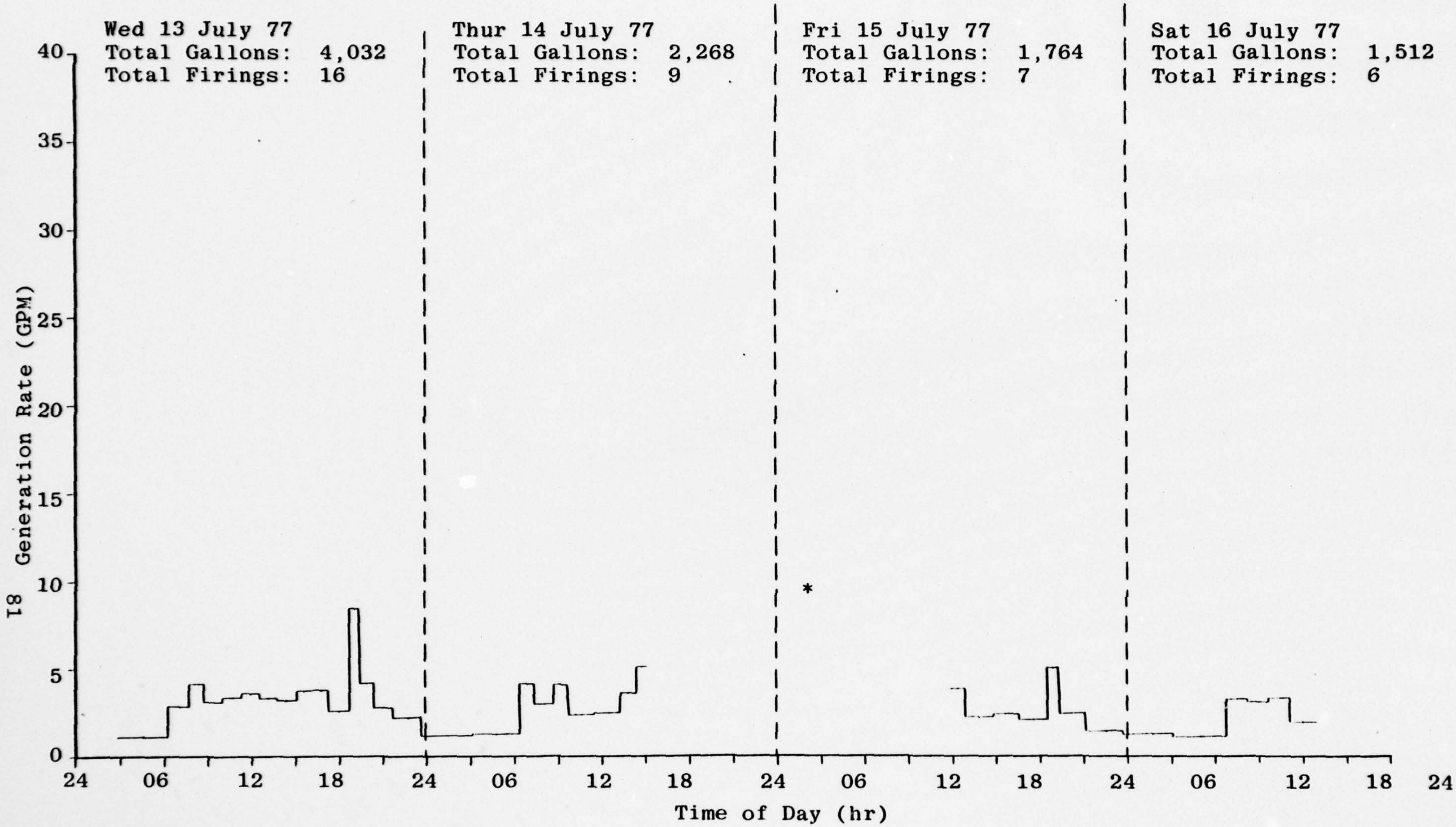
*Stopped recorder to change graph paper.

FIGURE 43 Generation Rate vs Time of Day USS ENGLAND Aft Pump Room



*Stopped recorder to change graph paper.

FIGURE 44 Generation Rate vs Time of Day USS HULL Fwd Pump Room



* No Data

FIGURE 45 Generation Rate vs Time of Day USS HULL Aft Pump Room

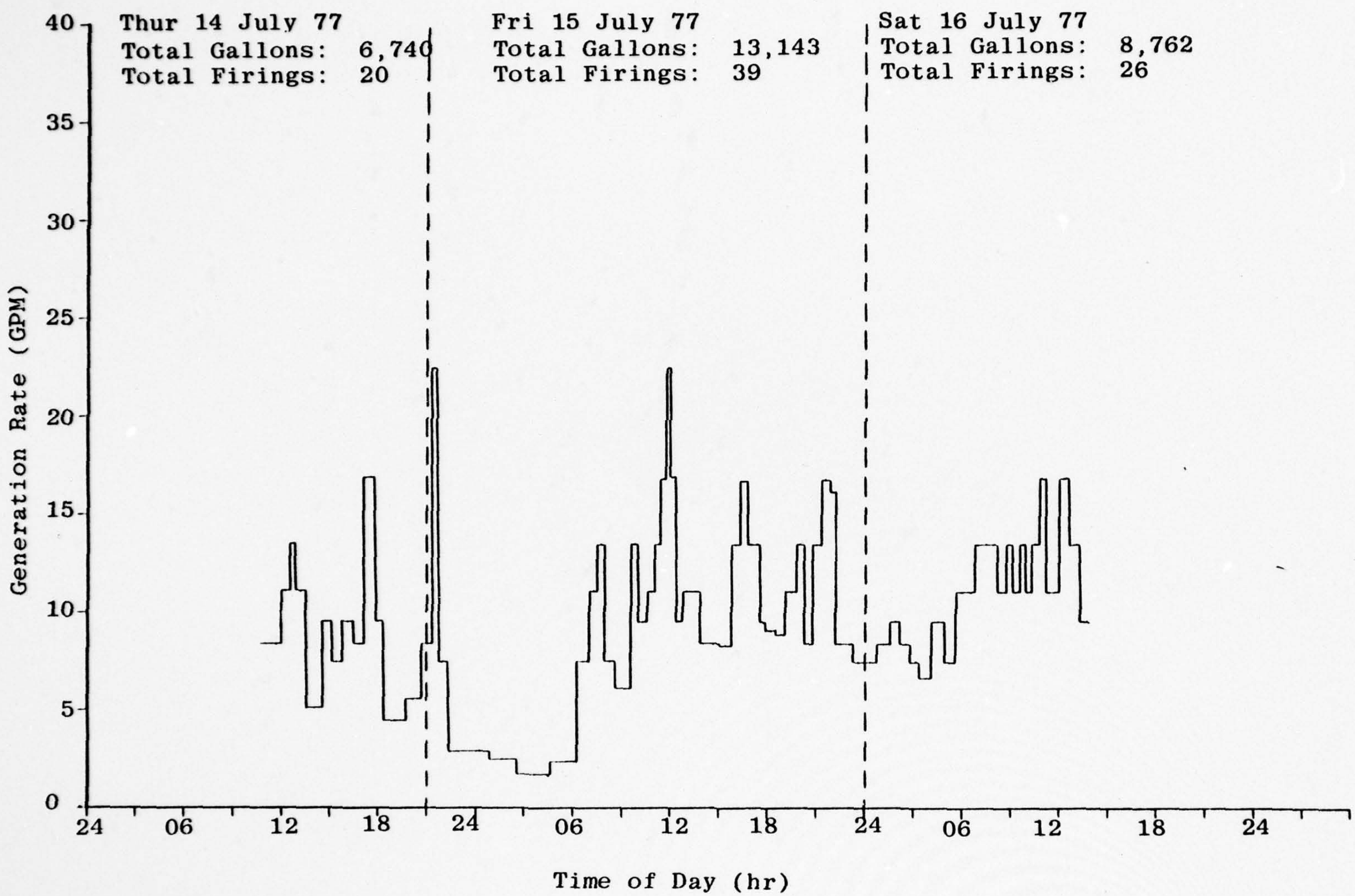


FIGURE 46 Generation Rate vs Time of Day USS HULL Fwd Pump Room (Out at Sea)

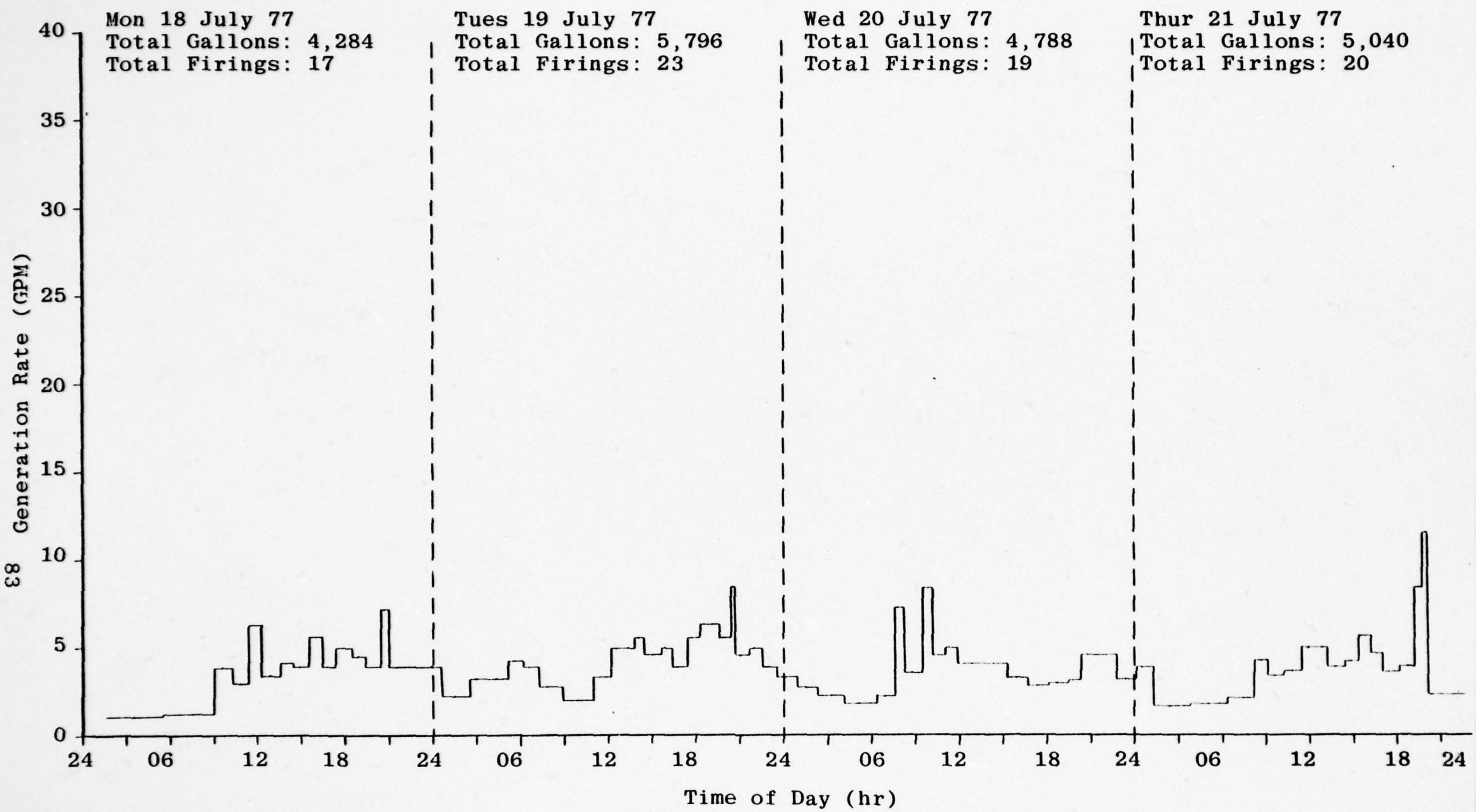


FIGURE 47   Generation Rate vs Time of Day   USS HULL   Aft Pump Room   (Out at Sea)

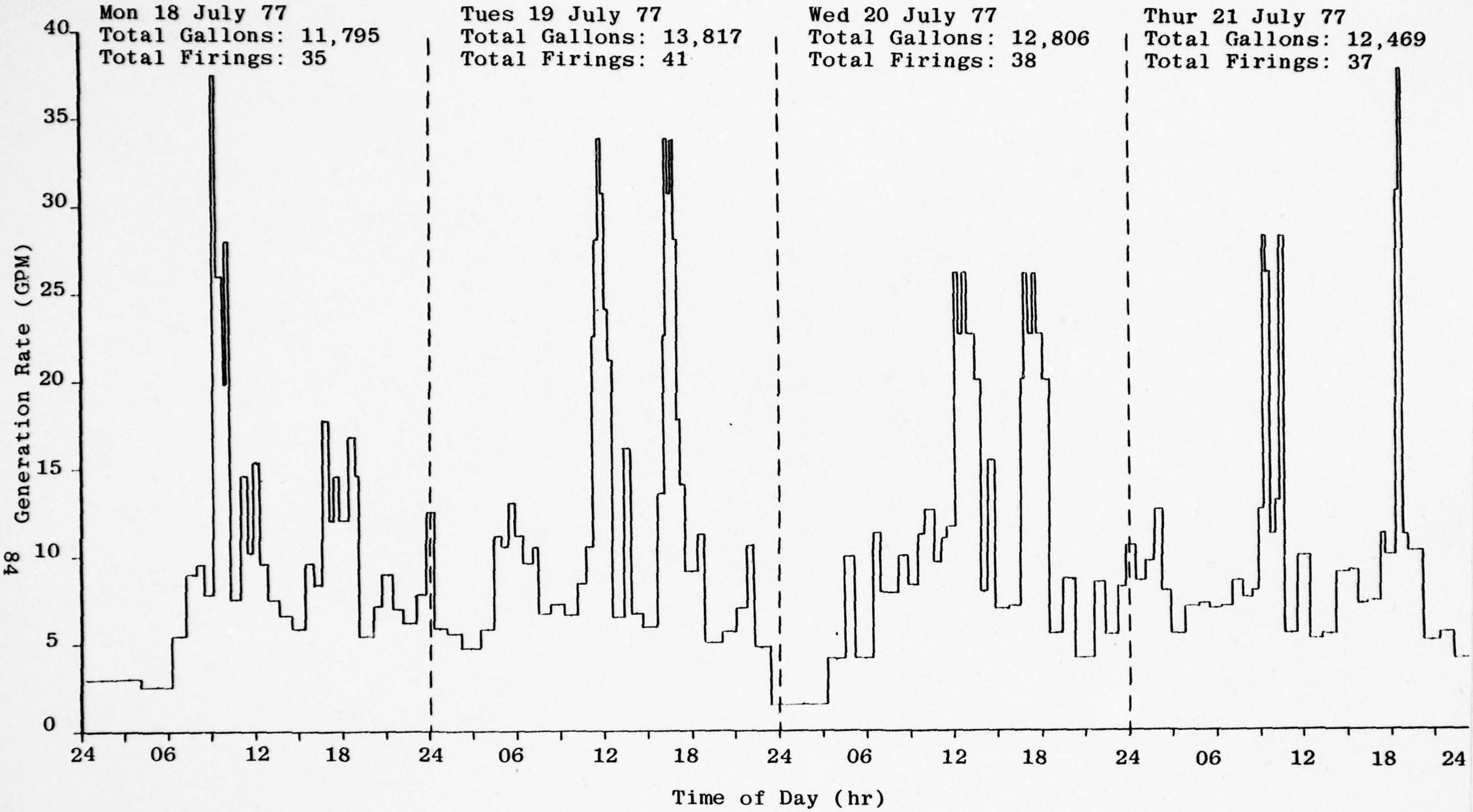


FIGURE 48 Generation Rate vs Time of Day USS HULL Fwd Pump Room (Weekend)

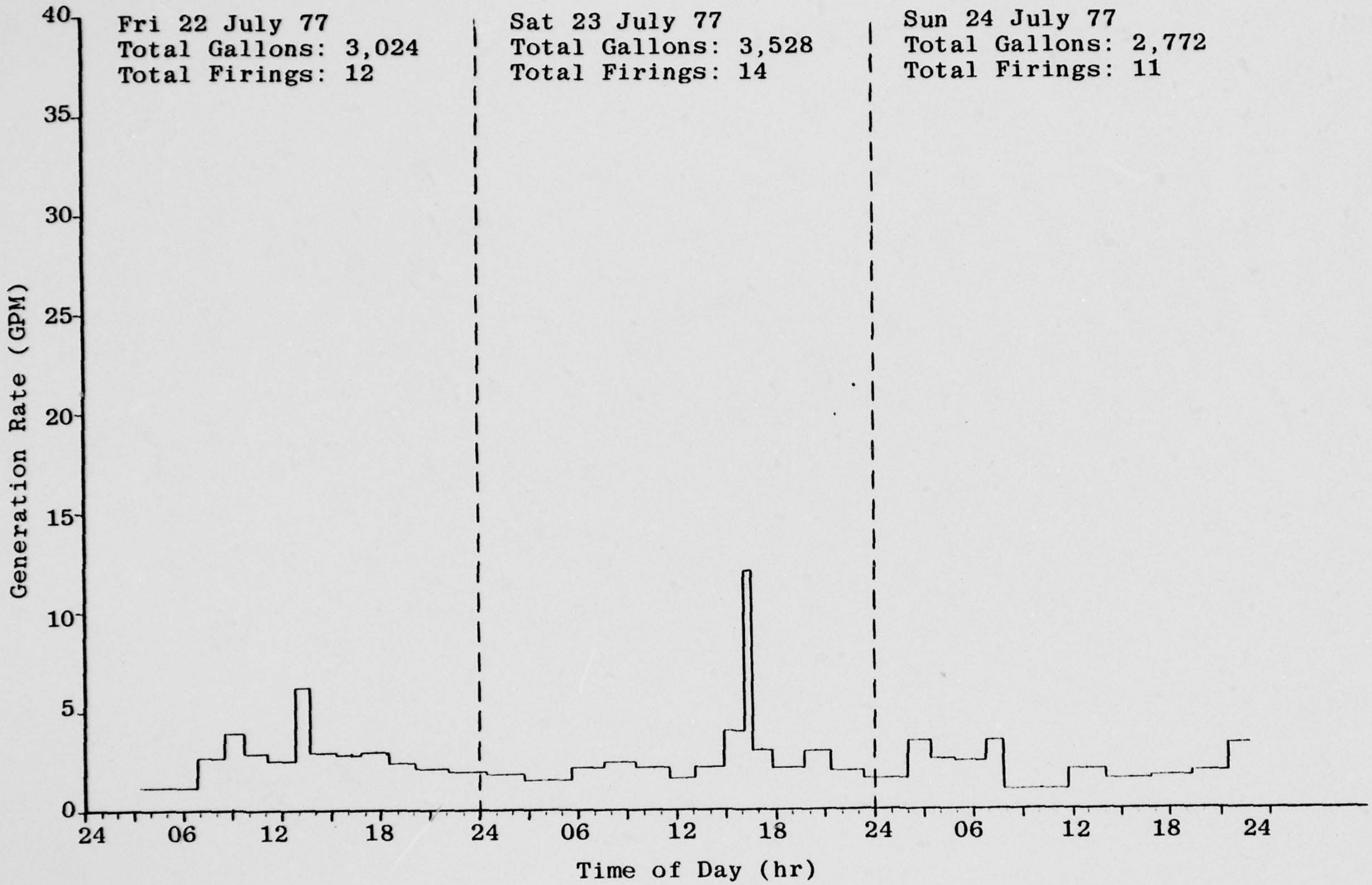


FIGURE 49 Generation Rate vs Time of Day USS HULL Aft Pump Room (Weekend)

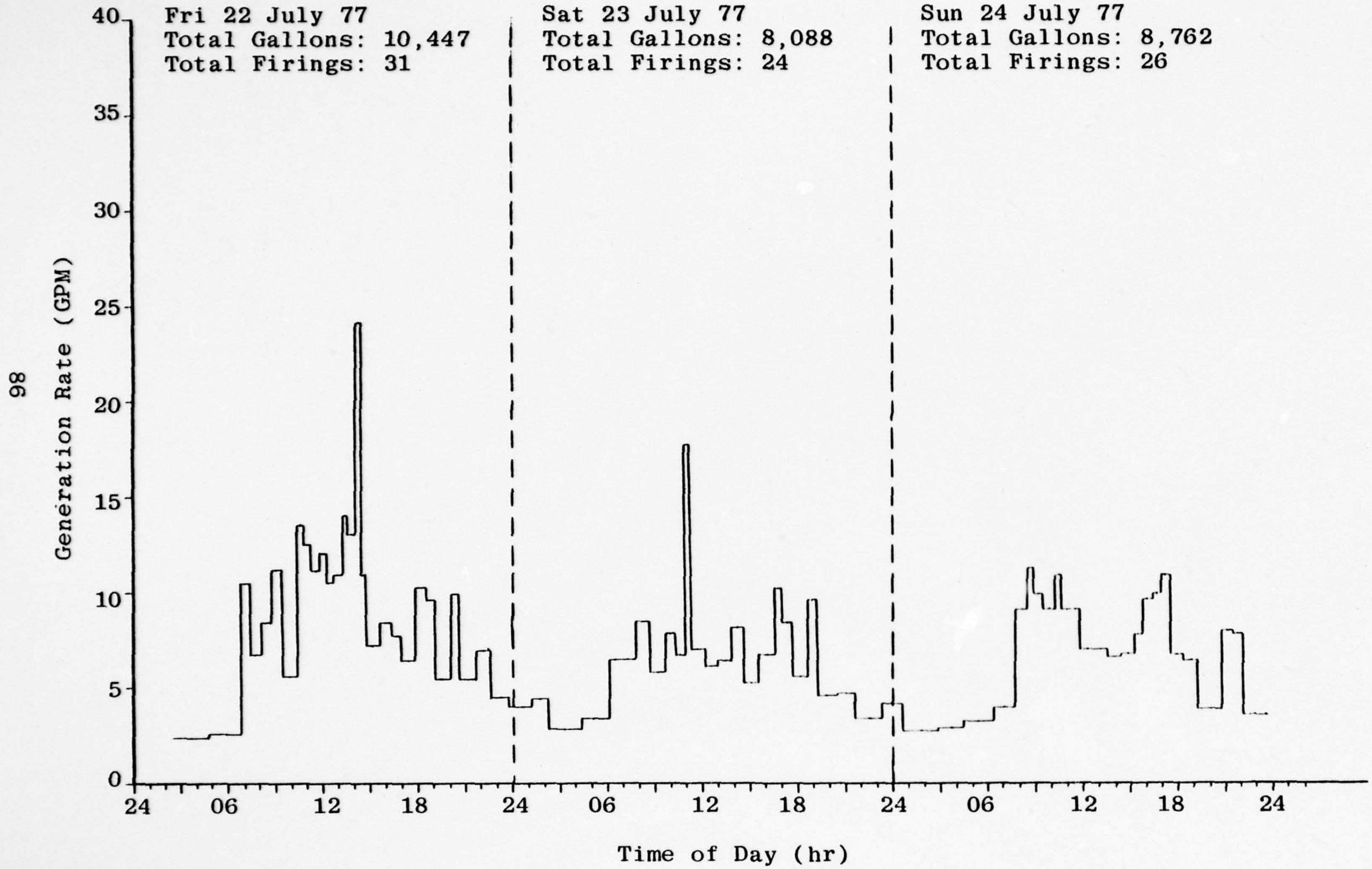


TABLE 11

TOTAL SEWAGE GENERATED - USS ENGLAND

26 to 29 April 1977

Tank Capacity: Forward - 232 Gallons
Aft - 168 Gallons

Day	Fwd Tank Firings	Fwd Tank Gallons	Aft Tank Firings	Aft Tank Gallons	Totals Firings	Totals Gallons
Wed 27th	7	1,624	21	3,528	28	5,152
Thur 28th	10	2,320	25	4,200	35	6,520
Fri 29th	11	2,552	37	6,216	48	8,768
Total (68 hrs.)	28	6,496	83	13,944	111	20,440
Daily Avg. (24 hrs.)	10	2,293	29.2	4,921	39	7,214

AD-A048 974 POLLUTION ABATEMENT ASSOCIATES CORTE MADERA CA F/G 13/2
FIELD INVESTIGATION OF SHIPBOARD/SHORESIDE SEWAGE TRANSFER SYST--ETC(U)
NOV 77 R W URBAN, D J GRAHAM, F J CAMPBELL N00014-77-C-0036
UNCLASSIFIED NL

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ADA048 974

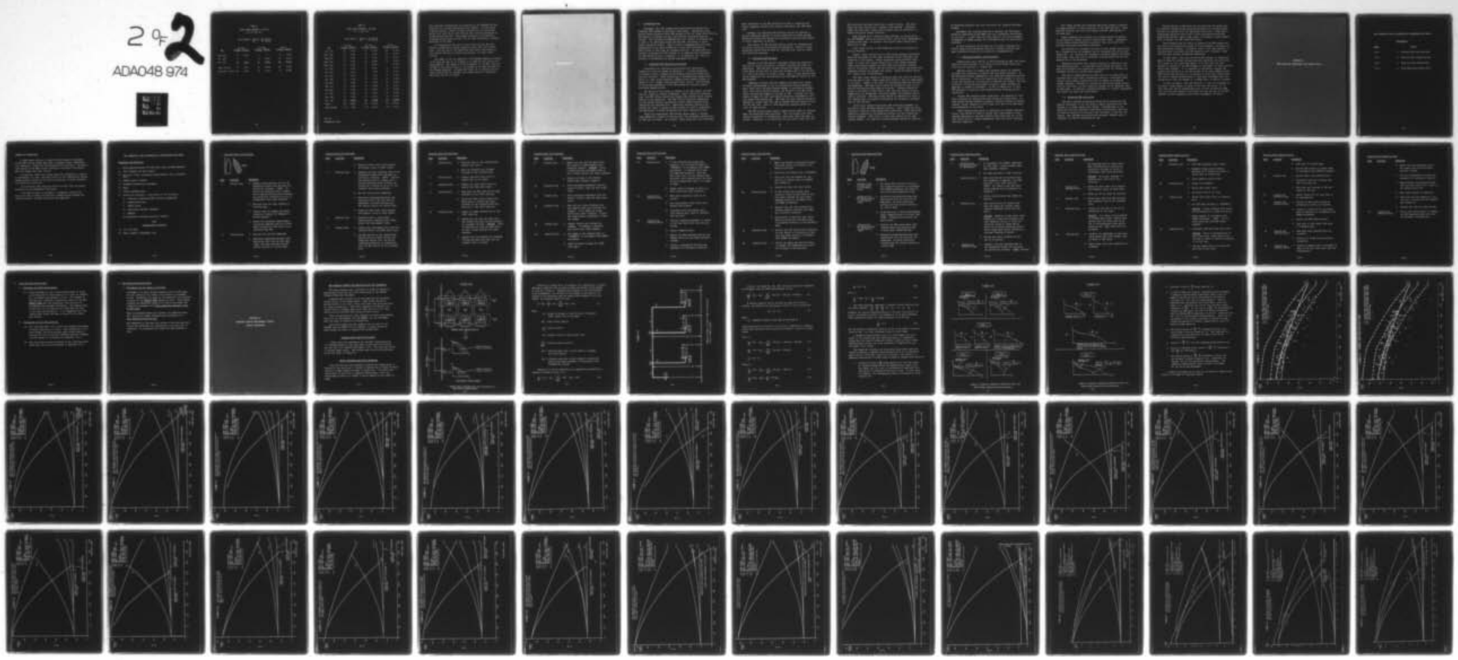


TABLE 12

TOTAL SEWAGE GENERATED - USS HULL

13 to 16 July 1977

Tank Capacity: Forward - 252 Gallons
Aft - 337 Gallons

Day	Fwd Tank Firings	Fwd Tank Gallons	Aft Tank Firings	Aft Tank Gallons	Totals Firings	Totals Gallons
Thur 14th	16	4,032	--	--	16	4,032
Fri 15th	--	--	30	10,110	30	10,110
Sat 16th	14	3,528	52	17,524	66	21,152
Total (52 hrs.)	30	7,560	82	27,634	112	35,294
Daily Avg. (24 hrs.)	14	3,489	38	12,754	52	16,290

TABLE 13

TOTAL SEWAGE GENERATED - USS HULL

17 - 31 July 1977

Tank Capacity: Forward - 252 Gallons
Aft - 337 Gallons

Day	Fwd Tank Firings	Fwd Tank Gallons	Aft Tank Firings	Aft Tank Gallons	Totals Firings	Totals Gallons
Sun 17th	10	2,520	32	10,784	42	13,304
*Mon 18th	17	4,284	35	11,795	52	16,079
*Tues 19th	23	5,796	41	13,817	64	19,613
*Wed 20th	19	4,788	38	12,806	57	17,594
**Thur 21st	20	5,040	37	12,469		17,509
Fri 22nd	12	3,024	31	10,447	43	13,471
Sat 23rd	14	3,528	24	8,088	38	11,616
Sun 24th	11	2,772	26	9,436	37	11,534
Mon 25th	14	3,528	28	9,436	42	12,964
Tues 26th	17	4,284	52	17,524	69	21,808
Wed 27th	14	3,528	38	12,806	52	16,334
Thur 28th	26	6,552	46	15,502	72	22,054
Fri 29th	17	4,284	53	17,861	70	22,145
Sat 30th	12	3,024	33	11,121	45	14,145
Sun 31st	15	3,780	24	8,088	39	11,868
Total	241	60,682	538	181,306	779	242,038
Daily Average	16.1	4,046	35.9	12,087	51.9	16,136

*At sea

**Dependents cruise

This continual flushing was not practiced on the ENGLAND and was reflected in its lower generation rate numbers. If continuous flushing from all a ship's urinals totaled only 10 gallons per minute, the total daily flow from the ship would be increased by 14,400 gallons per day. This common practice of continuously flushing urinals should account for the high difference in sewage generated on the HULL.

In reviewing all the data on both ships the aft CHT tank showed a significantly higher generation rate than the forward tank. This was due to the additional gray water load placed on this system from ship's laundry and galleys, all high volume sources.

The pumps in the aft pumproom of the ENGLAND pumped an average of 28 times per day vs. an average of 9 times per day for the forward pumproom. The pumps in the aft pumproom of the HULL fired an average of 36 times per day vs. an average of 16 times per day for the forward pumproom. Although CHT tanks are of similar size between forward and aft systems, this sizing does not necessarily mean their use will be equal.

7. RECOMMENDATIONS

Throughout the test program much experience was gained with shipboard CHT systems of different class ships. During this time, several ships activated their CHT systems at the San Diego Naval Station, and regular procedures for ship and pierside operations were developed. The following recommendations are a result of working with a total of 21 individual ships and with PWC, San Diego in their normal shoreside routine. Many of these recommendations have been implemented by the ships themselves or have been developed by Public Works at San Diego as standard practice. As additional experience is gained with CHT systems, it is expected that procedures for CHT operation will be updated. It is important that this experience is documented and shared throughout the fleet.

7.1 Shipboard CHT Operating Procedures

Procedures for connecting and disconnecting ships while berthed in a nest are shown in Appendix A. In these procedures, it should be noted, communications between ships and within each ship are critical. Ships connecting or disconnecting sewage hoses while in a nest should maintain communications between persons in charge or via a common sound-powered phone circuit. The problems of inter-ship dependence of the CHT systems are greatly reduced with good communications.

The duties of the person in charge of the CHT system, the CHT officer, should be clearly designated. When 2 ships are handling hose, the CHT officer aboard the inboard ship should retain overall control of the operation. The CHT officer should be responsible for the proper sanitary procedures closely supervising the hose connection and disconnection. Additional guidance should be developed for those in charge of CHT systems for them to understand the importance of proper procedures and their responsibilities.

Ships with operational CHT systems should begin to operate them immediately instead of waiting until the discharge restrictions of 1981 are in effect. As a result, these ships will have developed

more confidence in the CHT system and be able to identify and repair component malfunctions quickly long before the 1981 deadline.

Guidance for shipboard CHT operation should be updated to reflect experience gained in actual operations of these systems. Operating instructions should be continually evaluated and updated as fleet experience is gained.

The effects of CHT training schools should be assessed both by school visits and interviews with graduates. Specific recommendations should then be made for training aids, such as films, and curriculum updating.

7.2 Shipboard CHT Hardware

Because of the CHT system's redundant design and simplicity and lack of status indicators, component malfunctions often go undetected. This was most evident during the sewage monitoring tests where several days of data were unusable due to the failure of a 10% level sensor to secure a pump. Many of these malfunctions can go undetected for long periods with detrimental effects on the CHT hardware.

Component failures observed commonly included level sensor failures causing pumps to run on continuously without shutting down, check valve failures causing sewage to recirculate through the 4 inch solids overflow piping, and failure of the 30% level sensor causing both pumps to activate at 60%. A backup low level sensor or pump run time limit switch should be considered to prevent pumps from running dry. CHT tank low level sensors should be designed to insure that they can be removed without having to bail out the CHT tank. That is, they should be installed above the limit of pump suction.

The CHT control panel needs a system status light to indicate when the system has been activated. The low voltage trip relay should be modified to automatically reset when power has been restored. Presently, it is difficult for the crew to know that the

CHT controller has been reset after a power failure. The panel light and reset switch will eliminate this problem. Indicator lights for each level sensor could quickly give an indication of system status and sensor condition.

Some systems with 2 position pump switches, as installed on the USS ROANOKE, should be replaced with a switch that independently controls each pump. At present, this switch cannot selectively deactivate a pump.

Local alarm cutouts in CHT pumprooms should be installed as soon as possible.

Simple, clear instructions for CHT system checkout procedures should be developed to help ship personnel quickly determine the condition of the system. Simple procedures using portable sight tubes, to check level sensor sensitivity, level sensor sequence lights and pressure gauges can help identify potential problems both in the piping circuit and the electrical system long before full component failure can disable the system. These procedures should be a regular part of maintenance.

CHT deck risers should be installed such that they are parallel with the ship's side. Some risers were found to face at right angles to the side. Access to the riser for connecting hoses was difficult and dangerous. CHT deck risers should be checked for ease of connection and modifications made as required. Guidance should be given to the ships to help them so that they can safely rig hose. Suggestions for permanently installed saddles and brackets should also be provided. CHT deck risers should be installed as close to the outboard rail as possible, eliminating the crossing of passageways by the CHT hose.

AD-37 class tenders should have CHT receiving equipment installed at their mid-ship mooring stations. This alteration would eliminate a need for long sewage hose connections. Wash facilities should be installed at the mooring stations for crew cleanup and station washdown. Hose reels to store hose should not be used aboard tenders. All hose and related equipment should be supplied

by shoreside personnel who have facilities for cleaning and maintenance.

Equipment and clothing required to maintain the CHT system should be identified by MIL-SPEC and this information distributed to the fleet. It was found that many ships do not have equipment recommended by BUMED because this information has not been easily available.

As more shipboard CHT systems are activated, problems with system operation and hardware should be routinely reported and major problems followed up with specific recommendations.

7.3 Shoreside Hardware and Procedures

Powered hose reels similar to that developed by PWC, San Diego, should be made available to all Naval Stations where sufficient ship activity requires it (Figure 33).

Manning levels for sewage hose handling should be examined as additional experience is gained and more ships activated. As CHT operation becomes commonplace, the additional manpower required can be significant. Ports that experience high numbers of ship arrivals and departures, particularly on Mondays and Fridays, may have difficulty in meeting requirements without a great increase in manpower or change in procedure. It may be impractical to have PWC personnel on hand for each shipboard hose flushing and disconnection.

As more CHT systems become operational, the adequacy of salt water flushing for disinfecting hose should be re-evaluated. If hose grease buildup becomes a problem, effective methods of grease removal, either chemical or with steam, will have to be developed and promulgated to the field.

After flushing hose prior to disconnect at pressure manifold piers, care should be taken to insure that other ships or other systems operating on the same manifold have been shut off or the pier riser valve is closed immediately after salt water flushing has been completed.

Pier sewer systems with pressure manifolds present a problem in sewage backflow to ships connected to the same manifold. These backflow problems can occur even among different CHT systems on the same ship.

Those commands with pressure pier systems should be advised of the hazard of sewage backflow through open risers. Schematics of pier piping system should be placed at each pier riser with warnings and proper procedures explained.

Low pressure air blowdown fittings to drain sewage hose should be a standard piece of equipment for all shoreside activities (see Figure 39). All related hose equipment including adapter couplings, hose plugs, hose caps and air blowdown fittings should be the responsibility of the shoreside.

Shoreside personnel will require training in addition to the hose handling manual. As additional ports become activated, the need for personnel with appropriate training both for primary and secondary duties will become more apparent.

Salt water sewage generation rates are not as predictable as expected due to salt water consumption habits on individual ships. If salt water sewage loading will have an impact on shoreside sewage treatment, methods for continually monitoring sewage generation for each ship, so that equitable charges can be assessed, must be developed. In addition, shipboard guidance to control unnecessary salt water use should be investigated.

7.4 Shipboard CHT Activation

The major problem encountered during field testing was the general reluctance of all the ships to begin operating their CHT systems in a normal manner with sewage. Although many of the ships had certified systems or were near certification, they had no positive incentive to actually take the steps to activate the system. Most systems have sufficient problems, whether real or imagined, to justify postponing its use.

During testing, cooperation was enlisted from the ships only by carefully reviewing the operating principle of the CHT system and how it interacts with the shoreside facilities. Films and instructional materials were used to brief the Executive Officer, Engineering Officer, and in some cases, the Captain, before permission to operate the CHT system was given.

After working with the chief in charge of the CHT system and his crew in activating the system for test purposes, confidence in the system was attained. In several cases it was then possible to convince them to activate the CHT system in the "automatic" mode and routinely offload accumulated wastewater.

In some cases, even with certified CHT systems, an additional week of labor to correct malfunctions was necessary for activation. As a result of this testing program, it is felt that the true measure of success of the CHT program is the number of ships actually using their systems. It is necessary to personally explain the purpose and operation of the CHT system to all ship command levels. When activating the ship, it is necessary to work very closely with the crew to establish procedures so they gain confidence with the system and so that the danger of a sewage spill is greatly reduced.

To meet the April, 1981 CHT deadline, it will be necessary to activate a large number of ships in the next few years. It is felt that this can be accomplished only by ship activation teams that activate key vessels in key ports so that the use of the CHT systems is more widespread and visible throughout the fleet.

APPENDIX A

HOSE HANDLING PROCEDURES FOR NESTED SHIPS

CHT CONNECTING AND DISCONNECTING PROCEDURES FOR NESTS

Procedures

CONTROL OF OPERATIONS

A Chief Petty Officer or Junior Officer should be assigned as the CHT officer aboard each ship to assume overall responsibility during all connection and disconnection evolutions. He should have access to the X52J circuit during all evolutions and should give his orders over that circuit.

In addition, where one or more ships are attempting to connect or disconnect in a nest, the CHT officer on the inboard ship should assume overall control of the entire evolution to insure coordination during the evolution.

It is critical that positive control be kept over the entire evolution by one designated individual.

If no X52J circuit is available, a temporary circuit will have to be run to insure the positive communications between the control station, the deck risers and the pumprooms.

CHT CONNECTING AND DISCONNECTING INSTRUCTIONS FOR NESTS

<u>Equipment and Materials</u>

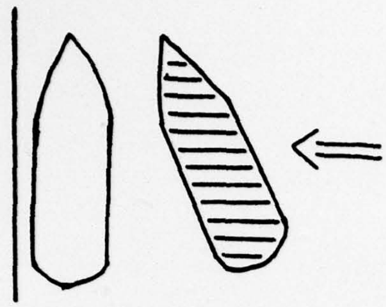
1. South-powered phones for each deck riser and CHT pumproom.
2. Valve handles for deck risers.
3. One coil of salt and pepper sound-powered phone extension wire.
4. Common plastic buckets.
5. Standard disinfectant detergent.
6. Rags.
7. Plastic gargage bags.
8. Protective clothing -- 6-12 pairs of the following:
   a. coveralls (rubberized NBC coveralls suggested)
   b. rubberized gloves
   c. rubber boots
   d. watch caps (machine washable)
   e. goggles

   All protective clothing should be labeled:

   "CHT"

   "CONTAMINATED CLOTHING"
9. L.P. air hose.
10. Short length of messenger line.

1. Outboard Ship Arriving Nest



STEP	LOCATION	PROCEDURE
1	Inboard ship	1. Assemble hose handling crew at the designated washup area and pass out protective clothing. (NOTE: Instruct the handling crew to remove their working uniform before donning the protective clothing so as not to contaminate their work uniforms.)
		2. Position hose for easy transfer to arriving ship.
		3. Inspect hose for damage and female connector fittings for damaged or missing gasqets.
		4. Obtain the necessary female/female connection adapters and LP air blowdown fittings for each riser to be connected from PWC.
2	Inboard ship	1. Man the fore and aft pumprooms.
		2. Establish sound-powered phone communication with fore and aft pumprooms, the deck stations and the control station on circuit X52J.

Outboard Ship Arriving Nest

STEP	LOCATION	PROCEDURE
		3. Break out deck riser valve handles and bucket; place at deck risers.
3	Outboard ship	1. Assemble the hose handling crew at the designated washup area and pass out protective clothing. (NOTE: Instruct the handling crew to remove their working uniforms before donning the protective clothing so as not to contaminate their work uniforms.)
		2. Man the fore and aft pumprooms.
		3. Establish sound-powered phone communications with the fore and aft pumprooms, the deck stations and the control station on circuit X52J.
		4. Break out deck riser valve handles and buckets; place at deck risers.
4	Outboard ship	1. Establish ship to ship sound-powered phone communications (X52J) using "salt and pepper" cable.
5	Inboard ship	1. Connect salt and pepper wire from the outboard ship to the X52J phone jack.
		2. The CHT officer on the inboard ship should check his phone circuit and establish control over the entire connecting operation in cooperation with the CHT officer on the outboard ship.

Outboard Ship Arriving Nest

STEP	LOCATION	PROCEDURE
6	Inboard ship	1. Pass the hose to the outboard ship (female end first).
		2. Pass low pressure air blowdown fittings to the outboard ship.
7	Inboard ship	1. Inspect the deck riser valve to insure that it is closed.
8	Outboard ship	1. Inspect all deck riser valves to insure that they are closed.
9	Inboard ship	1. Pump down the CHT tank and set pump switches to the "OFF" position.
		2. Check with CHT officer aboard outboard ship to insure that pump switches on the outboard ship have been set to the "OFF" position.
10	Outboard ship	1. Insure all pump switches are in the "OFF" position.
		2. Remove the cap from the deck riser and connect the hose and low pressure air blowdown fitting. CAUTION: Prior to removing cap from the deck riser or hose, insure neither are under pressure.
		3. Inspect the low pressure air blowdown fitting and make sure that the air bleeder valve is closed.

Outboard Ship Arriving Nest

STEP	LOCATION	PROCEDURE
11	Inboard ship	1. Remove the cap from the deck riser and connect a female/female hose connector adapter. CAUTION: Prior to removing caps from deck riser or hose, insure neither are under pressure.
		2. Connect the hose to the female/female hose connector adapter.
12	Outboard ship	1. After obtaining permission from the control officer, open the deck riser valve.
13	Inboard ship	1. After obtaining permission from the control officer, open the deck riser valve.
14	Outboard ship	1. Open the salt water flushing line and inspect deck riser fittings for leakage. If no leaks are found, secure salt water flushing. Correct any leaks before attempting to transfer sewage.
15	Inboard ship	1. Inspect risers and fittings for leakage. If leakage is detected, have other ship cease pumping.
16	Outboard ship	1. Set pumps on the outboard ship to "AUTOMATIC" in accordance with SDOSS procedures.
		2. Check the deck fittings for leaks once again.

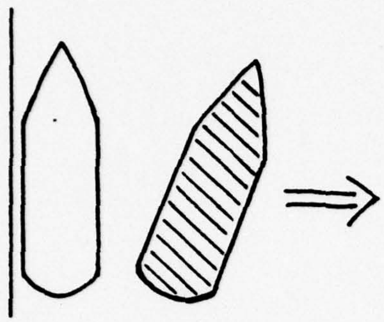
Outboard Ship Arriving Nest

STEP	LOCATION	PROCEDURE
17	Inboard ship	1. If the outboard ship pumps down properly, set the pump switches to "AUTOMATIC" in accordance with SDOSS procedures. If outboard ship does not pump down properly, close the deck riser valve on the inboard ship and leave valve secured until notified by the outboard ship that it is ready to pump.
		2. Repeat steps 6 through 17 until all deck risers have been connected.
18	Inboard and outboard ships	1. Wash down connection areas as required.
		2. Stow head phones, deck riser valve handles and buckets.
		3. Disconnect salt and pepper cable from inboard ship' pass to outboard ship and stow.
19	Inboard and outboard ships	1. Instruct pumproom personnel to return to the last deck riser that was connected.
		2. Secure communications.
		3. Muster the deck handling crew at the washup facilities and begin personal cleanup.
		4. Collect contaminated clothing and segregate for washing as required.

Outboard Ship Arriving Nest

STEP	LOCATION	PROCEDURE
		5. Empty the buckets containing spillage from deck risers into heads at the washup facilities.
		6. Disinfect the buckets with a detergent.
		7. After the crew has washed up, call the roll to insure that all members have washed up.
		8. Dismiss the crew for other duties.
20	Outboard ship	1. If the system has not been used recently, allow the CHT tank to fill with water through the salt water washdown nozzle in accordance with the SDOSS procedures.
		2. Observe that the level sensors are working properly and that the pumps are cycling as required.
		3. Discontinue filling with salt water when satisfied that the CHT system is operating properly in the automatic mode.
21	Outboard ship	1. Convert the CHT system from collection of soil drains to collection of both soil and waste drains in accordance with SDOSS procedures.
22	Outboard ship	1. Notify the sound and security watch to inspect CHT pumprooms every hour for evidence of malfunctions.

2. Outboard Ship Departing Nest



STEP	LOCATION	PROCEDURE
1	Outboard ship (2 hours prior to disconnect time)	1. Set waste drain diverter valves to the overboard position in accordance with SDOSS procedures two hours before the planned departure time.
2	Outboard ship (30 minutes prior to disconnect time)	1. Establish sound-powered phone communications with the fore and aft pumprooms, the deck connection stations and the control stations on circuit X52J.
		2. Establish ship to ship sound-powered phone communications on circuit X52J, (NOTE: Outboard ship provide the phone cable.)
3	Inboard ship (30 minutes prior to disconnect time)	1. Receive the X52J phone cable from outboard ship and establish ship to ship phone communications.
		2. Establish sound-powered phone communications with the fore and aft pumprooms, the deck connection stations and the control station on circuit X52J.

Outboard Ship Departing Nest

STEP	LOCATION	PROCEDURE
4	Outboard ship (30 minutes prior to disconnect)	1. In accordance with SDOSS, pump down all CHT tanks. Inform inboard ship when pumpdown complete.
		2. Set pump switches on "OFF" position.
	Inboard ship(s)	1. Upon notification by outboard ship that pumpdown is complete, set pump switches to the "OFF" position. (NOTE: All ships in the nest must secure pumping until disconnect is complete.)
		2. Notify outboard ship that pumps are secured.
5	Outboard ship	1. Upon notification by inboard ship that the pumps are secured, begin flushing discharge lines with salt water.
		CAUTION: Whenever a high level alarm sounds, all ships stop flushing, and take immediate action to close the isolation valves on those drains below the overboard discharge and/or divert upper deck drains overboard to preclude flooding of spaces.
		2. Secure salt water flushing at the end of 10 minutes.
6	Inboard and outboard ships	1. Assemble the hose handling crew at the designated washup area and pass out protective clothing. (NOTE: Instruct

<u>Outboard Ship Departing Nest</u>

STEP	LOCATION		PROCEDURE
			the handling crew to remove their work uniforms before donning the protective clothing so as not to contaminate their work uniforms.)
			<u>CAUTION</u>: No eating, smoking, or drinking until the end of the evolution.
7	Inboard and outboard ships	1.	Break out deck riser valve handles and brackets; place at deck riser.
		2.	Break out LP air hoses as required.
8	Inboard ship	1.	Obtain hose caps from PWC and pass the necessary caps to the outboard ship.
9	Outboard ship	1.	Connect LP air hose to the LP air connection at the riser.
			<u>CAUTION</u>: If a delay is anticipated in blowing down hoses, inboard ship should close its deck riser so as not to re-contaminate hose during delay period. Open valve prior to blowdown.
10	Inboard ship	1.	Instruct all pumprooms to jack open check valves and allow sewage lines to drain to CHT tanks.
		2.	Reset check valve upon completion of blowdown.

Outboard Ship Departing Nest

STEP	LOCATION	PROCEDURE
11	Outboard ship	1. Jack open pumproom check valves.
		2. Commence sewage hose blowdown. Continue for 5 minutes in order to insure hose in liquid free.
		3. Close pumproom check valves.
12	Outboard ship	1. Secure air blowdown.
		2. Secure deck riser valve.
		3. Disconnect the LP air line.
13	Inboard ship	1. Secure deck riser valve to outboard ship.
		2. Set CHT pump switches to "AUTOMATIC."
		CAUTION: Insure outboard deck risers are secured prior to pump activation.
		3. Begin pumping in accordance with SDOSS procedures. (NOTE: All inboard ships may continue normal pumping.)
14	Outboard ship	1. Disconnect CHT hose from deck riser.
		CAUTION: Prior to disconnection of hose from riser, crack open LP air fitting on riser to insure no pressure is in the line.
		2. Cap the female end of the hose and male end of the riser.

Outboard Ship Departing Nest

STEP	LOCATION	PROCEDURE
		3. Pass hose to inboard ship.
		4. Operate CHT system in transit mode in accordance with SDOSS procedures.
15	Inboard ship	1. Receive hose from outboard ship.
		2. Disconnect hose and fittings from deck riser and cap.
		3. Pass hose and fittings to PWC personnel on the pier.
16	Inboard and outboard ships	1. Repeat steps 9-15 for each hose to be disconnected.
17	Inboard and outboard ships	1. Insure all deck riser valves on disconnected risers are secured.
		2. Insure all ships are in the proper mode of operation in accordance with SDOSS procedures.
		3. Secure the X52J phone circuit.
		4. Pass ship to ship phone line back to outboard ship.
18	Inboard and outboard ships	1. Wash down hose handling areas as required.
		2. Re-stow all items used during disconnection.
19	Inboard and outboard ships	1. Instruct pumproom crew to assemble on deck at the last deck riser that was disconnected.

Outboard Ship Departing Nest

STEP	LOCATION	PROCEDURE
		2. Muster the deck handling crew at the washup facilities and begin personal cleanup.
		3. Collect contaminated clothing and segregate for washing as required.
		4. Empty buckets containing spillage from the deck risers into a head at the washup facilities.
		5. Wash these buckets as required.
		6. After the crew has washed up, call the roll to insure that all members have washed up.
		7. Dismiss the crew for other duties.
20	Inboard and outboard ships	1. Notify the roving patrol to inspect the CHT pumprooms every two hours for evidence of malfunction.

3. Ship Arriving Inboard Nest

A. Procedure for Ships Being Moved

(1) A ship movement by one or more nested ships to allow an arriving ship to move directly to a pier is treated as a disconnect and movement to sea. All vessels in the nest are, therefore, required to shift to the CHT TRANSIT MODE and then disconnect from the pier in accordance with standard procedures. The inboard ship of the nest will be required to flush down the hose to the pier and disconnect. It is suggested that the inboard ship retain the hose on board for the later nest hookup.

B. Procedures for the Ship Arriving

(1) The "arriving ship" will follow the standard procedures of ships connecting to a pier. Upon completion of the pier hookup, the arriving ship shall stand ready to receive the rest of the nest outboard and then commence the CHT hookup in accordance with Appendix A-4-1.

(2) The nest ships arriving outboard of the "arriving ship" shall also follow the procedures of Appendix A-4-1.

4. Ship Departing Inboard Nest

A. Procedures for all Ships in the Nest

A movement of a ship berthed inboard a nest of CHT ships will be treated by all ships in the berth as a movement to sea. Therefore, all ships in the berth will be required to shift to the TRANSIT MODE during the move. Those ships outboard the departing vessel will follow the normal disconnection procedures for ships departing outboard a nest of CHT ships.

When the outboard ships have cleared, the departing ship will follow the normal disconnection procedures of a ship departing from the pier.

The remainder of the nest will return to the pier and will follow the procedures for connecting to the pier and, if necessary, the procedures for ships arriving outboard a nest.

APPENDIX B

MEASURED SYSTEM PERFORMANCE CURVES

CHTSIM COMPARISON

THE GRAPHICAL METHOD FOR PREDICTING CHT PUMP FLOWRATES

CHT pump flowrates were calculated by using the method of adding pump curves and line loss curves shown in the CHTSIM Flowrate Prediction Procedure.

Flowrates were calculated for each pump and CHT discharge piping circuit of the ships tested. Pump curves and ship's piping friction (line loss) curves from field test data were used for these calculations. These were compared to flowrates calculated from an averaged pump curve, hose friction (line loss) curves and the corrected ship piping friction factor.

These calculations have been compared to actual ship pumping rates for the USS ENGLAND, the USS BROOKE, and the USS ROARK. They are shown in Figures B-2 through B-21.

Calculated predictions are compared for the nest of the ENGLAND and the JOUETT for the combined, two-ship flowrates. These graphs are shown in Figures B-22 through B-29.

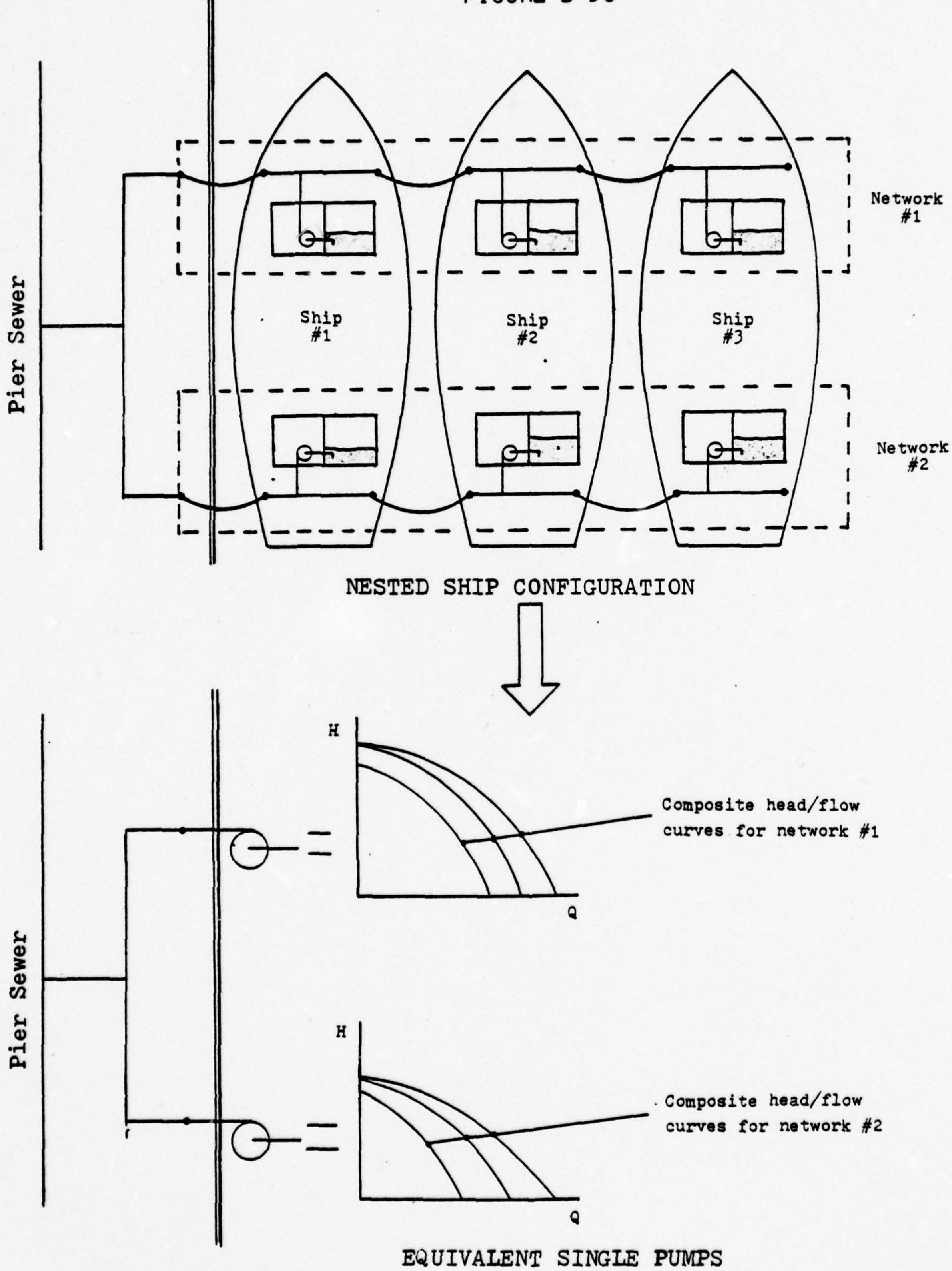
AVERAGED PUMP CURVE CALCULATIONS

A pump curve that represents the "average" characteristics of a Peabody Barnes 70 foot head pump was developed by plotting the test data for shipboard CHT pumps tested. The curve was fitted to average these points. The average pump curve and related data points are shown in Figure B-1.

CHTSIM FLOWRATE PREDICTION PROCEDURE

Both fore and aft flow networks of nested ship pumps shown in Figure B-30 are equivalent to parallel combinations of pumps discharging into a common header as shown in Figure B-31. The method described below to solve for a composite head/flowrate curve for three pumps at Point A of Figure 2 can be adpated to any number of pumps.

FIGURE B-30



Nested Ship Configuration and Conversion to Equivalent Single Pumps

Referring to Figure B-31, an equation for conservation of energy (Bernoulli equation) can be written from the surface of the sewage in tank #3 to Point C. Assuming the pressure at the tank surface to be atmospheric, the velocity of the sewage in the tank at its surface to be negligible and the nominal pipe diameter to be four inches, the equation takes the form.

$$Z + HP_3 = \frac{Pc}{\gamma} + Zc + \frac{Q_3^2}{2gA^2} + HL_5 + HL_6 \qquad (1)$$

Where

Z_3 = height of sewage in tank #3 above a reference level (water line of the ship)

HP_3 = head across pump #3

$\frac{Pc}{\gamma}$ = head at point C

Zc = height of point C above water line

$\frac{Q_3^2}{2gA^2}$ = velocity head at point C

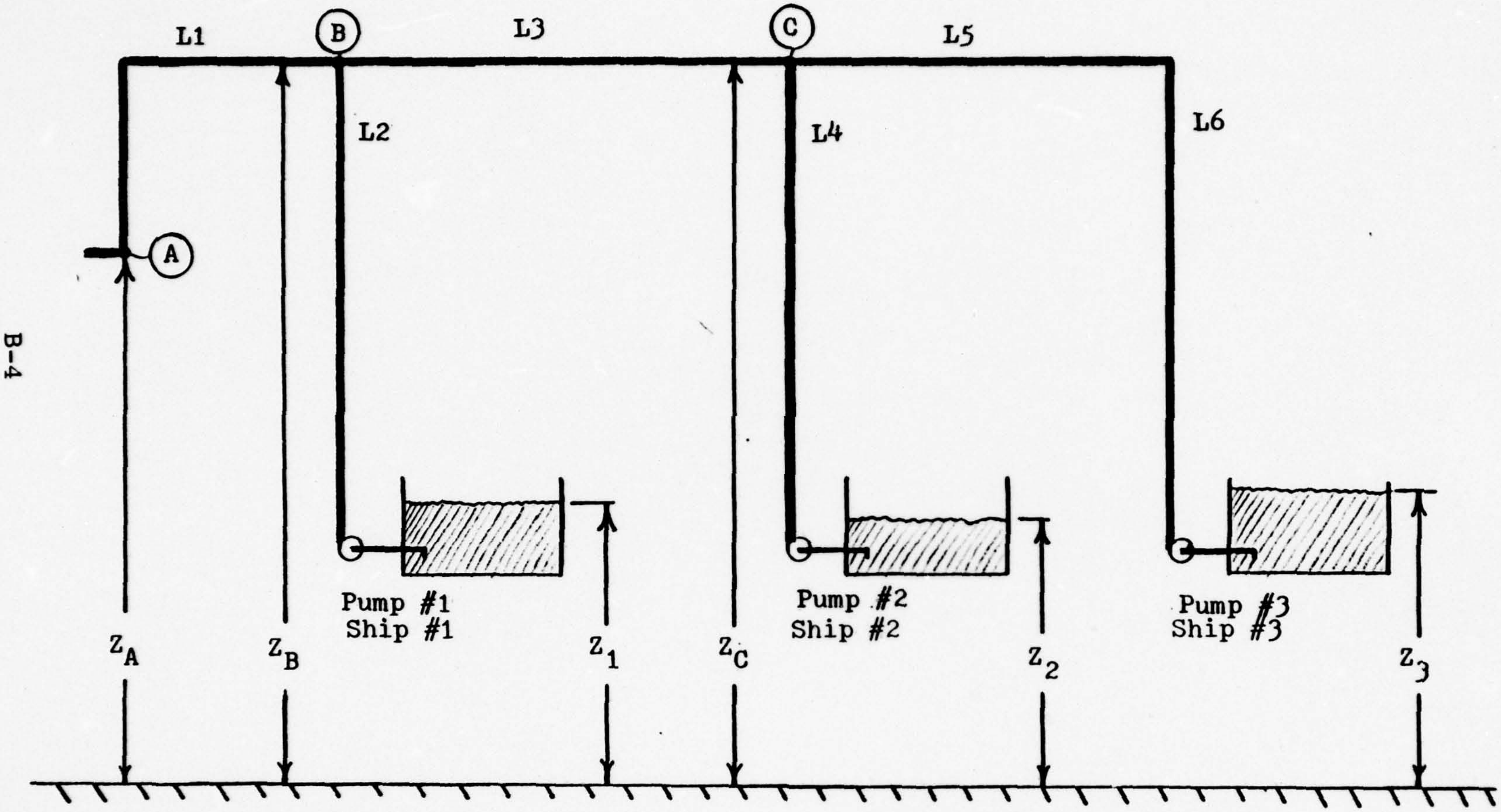
HL_5 = friction head loss in pipe length 5 (through-hull ship piping)

HL_6 = friction head loss in pipe length 6 (connection piping from pump discharge to intersection with through-hull piping)

Equation (1) can be rewritten as a compatibility equation to express the head at point C as

$$\frac{Pc}{\gamma} = (Z_3 - Z_C) - \frac{Q_3^2}{2gA} - HL_5 - HL_6 + HP_3 \qquad (2)$$

FIGURE B-31



Hydraulic Model of Three Pumps Discharging
Into a Common Header

Finally, the terms HL_5, HL_6, HP_3 can more clearly be expressed as functions of Q_3 by rewriting equation (2) as:

$$\frac{Pc}{\gamma} = (Z_3 - Z_c) - \frac{Q_3^2}{2gA^2} - HL_5(Q_3) - HL_6(Q_3) + HP_3(Q_3) \qquad (3)$$

A similar equation can be written for pump #2 at Point C. Finally, the equation of continuity of point C can be written as:

$$Q_c = Q_3 + Q_2 \qquad (4)$$

Where

Q_c = combined flowrate from pump #2 and pump #3

Using equations of the form of (3) and (4), equations for compatibility and continuity can be written at Points A, B and C as shown below.

Point C

$$\frac{Pc}{\gamma} = (Z \quad - Z_c) - \frac{Q_3^2}{2gA^2} - HL_5(Q_3) - HL_6(Q_3) + HP_3(Q_3) \qquad (5)$$

$$\frac{Pc}{\gamma} = (Z_2 - Z_c) - \frac{Q_2^2}{2gA^2} - HL_4(Q_2) + HP_2(Q_2) \qquad (6)$$

$$Q_c = Q_1 + Q_2 \qquad (7)$$

Point B

$$\frac{P_B}{\gamma} = (Z_1 - Z_B) - \frac{Q_1^2}{2bA^2} - HL_2(Q_1) + HP_1(Q_1) \qquad (8)$$

$$\frac{P_B}{\gamma} = (Z_c - Z_B) + \frac{Pc}{\gamma} - HL_3(Q_c) \qquad (9)$$

$$Q_B = Q_1 + Q_c \tag{10}$$

Point A

$$\frac{P_A}{\gamma} = (Z_B - Z_A) + \frac{P_B}{\gamma} - HL_1(Q_B) \tag{11}$$

The above equations represent a system of seven equations and the eight unknowns: $\frac{P_c}{\gamma}$; $\frac{P_B}{\gamma}$; $\frac{P_A}{\gamma}$; Q_3 ; Q_2 ; Q_1 ; Q_c ; Q_B . Normally the friction characteristics of the pipe from point B to point C are known and point A is assumed to be an open discharge. These assumptions permit an eighth equation to be written

$$\frac{P_A}{\gamma} = 0.0 \tag{12}$$

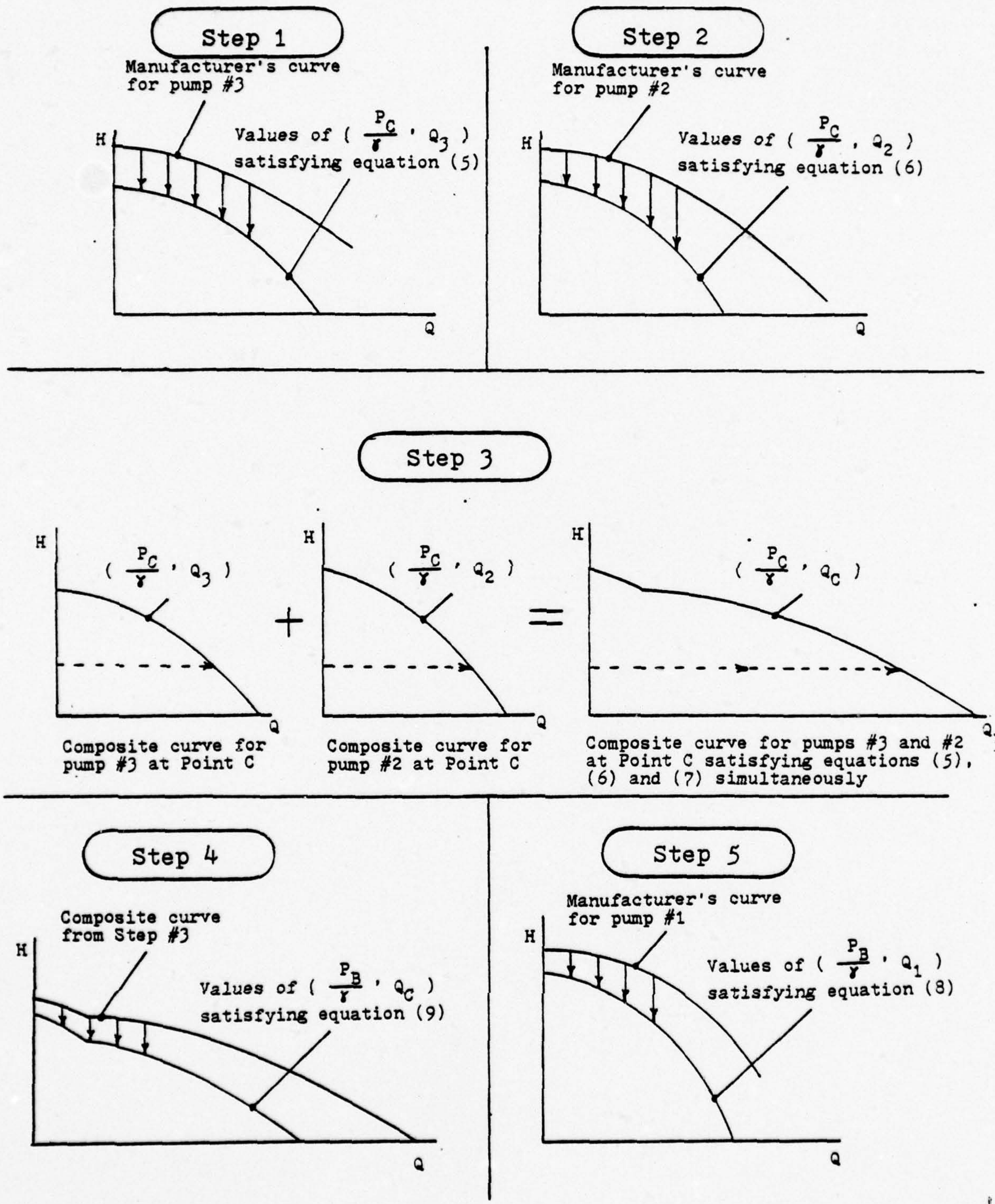
and the system of equations could be solved to determine a specific value for Q_B - the total discharge from all three pumps.

A composite head/flowrate curve for three pumps (the equivalent of the single pump case described above) is computed by noting that the locus of head and flowrate values at Point A must simultaneously satisfy the seven equations of compatibility and contunuity (5-11) above.

The numerical procedure for satisfying these seven equations thereby producing a composite head/flowrate curve of an equivalent pump at point A (the pier riser) is as follows. For clarity, a graphical description of these steps is shown in Figures B-32 and B-33

1. Calculate values of $\frac{P_c}{\gamma}$ using equation (5) over the range of flowrates permitted by the manufacturer's pump curve. The result will be a set of coordinates of head and flowrate which if connected would form a curve. At each value of flowrate, the corresponding head is calculated by using equation (5).

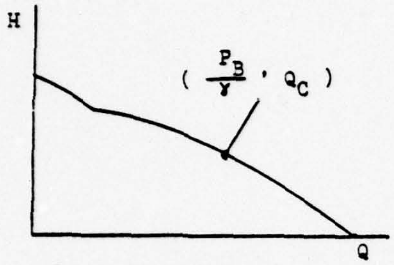
FIGURE B-32



Steps to Generate Composite Head/Flow curve for Three Pumps Operating Simultaneously

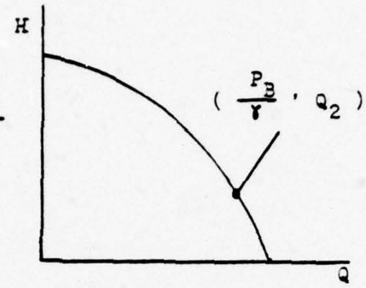
FIGURE B-33

Step 6



Composite curve for pumps #3 & #2 at Point B

+



Composite curve for pump #1 at Point B

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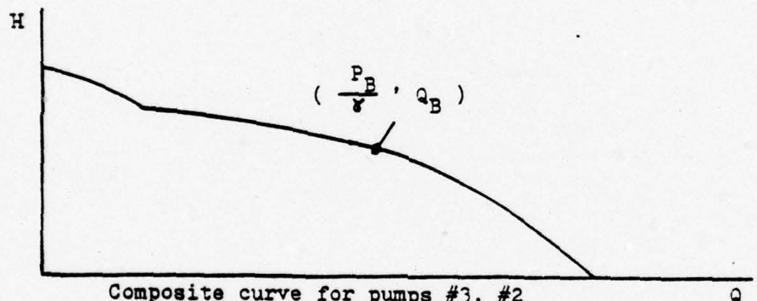
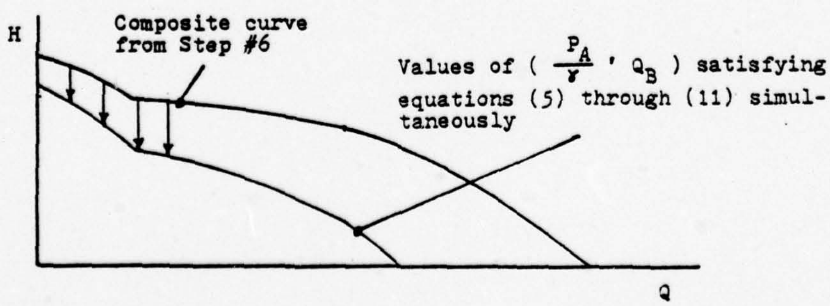


Composite curve for pumps #3, #2 & #1 at Point B satisfying equations (5),(6),(7),(8),(9) and (10) simultaneously

---

Step 7



Steps to Generate Composite Head/Flow Curve for Three Pumps Operating Simultaneously

2. Calculate values of $\frac{Pc}{\gamma}$ using equation (6).

3. A locus of head and flowrate coordinates which represent a composite head/flowrate (equivalent pump) curve for pumps #3 and #2 can now be determined by satisfying equations (5), (6), and (7) simultaneously. That is, matching head coordinates from from Steps 1 and 2 are found (i.e., equations (5) and (6) are satisfied simultaneously for $\frac{Pc}{\gamma}$). At this value of $\frac{Pc}{\gamma}$, the corresponding flowrate Q_c must equal the sum of flowrate coordinates used to produce $\frac{Pc}{\gamma}$ in equations (5) and (6) (equations (5), (6), and (7) are satisfied simultaneously). This step is equivalent to the classic technique of adding two pump curves horizontally to obtain a head/flowrate curve for parallel pump operation.

4. The paired values of $(\frac{Pc}{\gamma}, Q_c)$ produced in Step 3 can now be used to satisfy equation (9). The equations for compatibility and continuity at Point B can now be satisfied simultaneously.

5. Values of $(\frac{P_B}{\gamma}, Q_2)$ are then computed using equation (8).

6. Step 3 is repeated using values of $(\frac{P_B}{\gamma}, Q_c)$ from Step 3 and $(\frac{P_B}{\gamma}, Q_2)$ from Step 5.

7. The paired values of $(\frac{P_B}{\gamma}, Q_B)$ produced in Step 6 can now be used to satisfy equation (11). Equations (5) through (11) are now satisfied simultaneously. The composite head/flowrate curve at point A for pumps #1, #2, #3 is now determined.

A similar procedure can be used for all parallel combinations; three or two pumps or individual pumps.

FIGURE B-1 AVERAGE PUMP HEAD/FLOW RATE CURVE

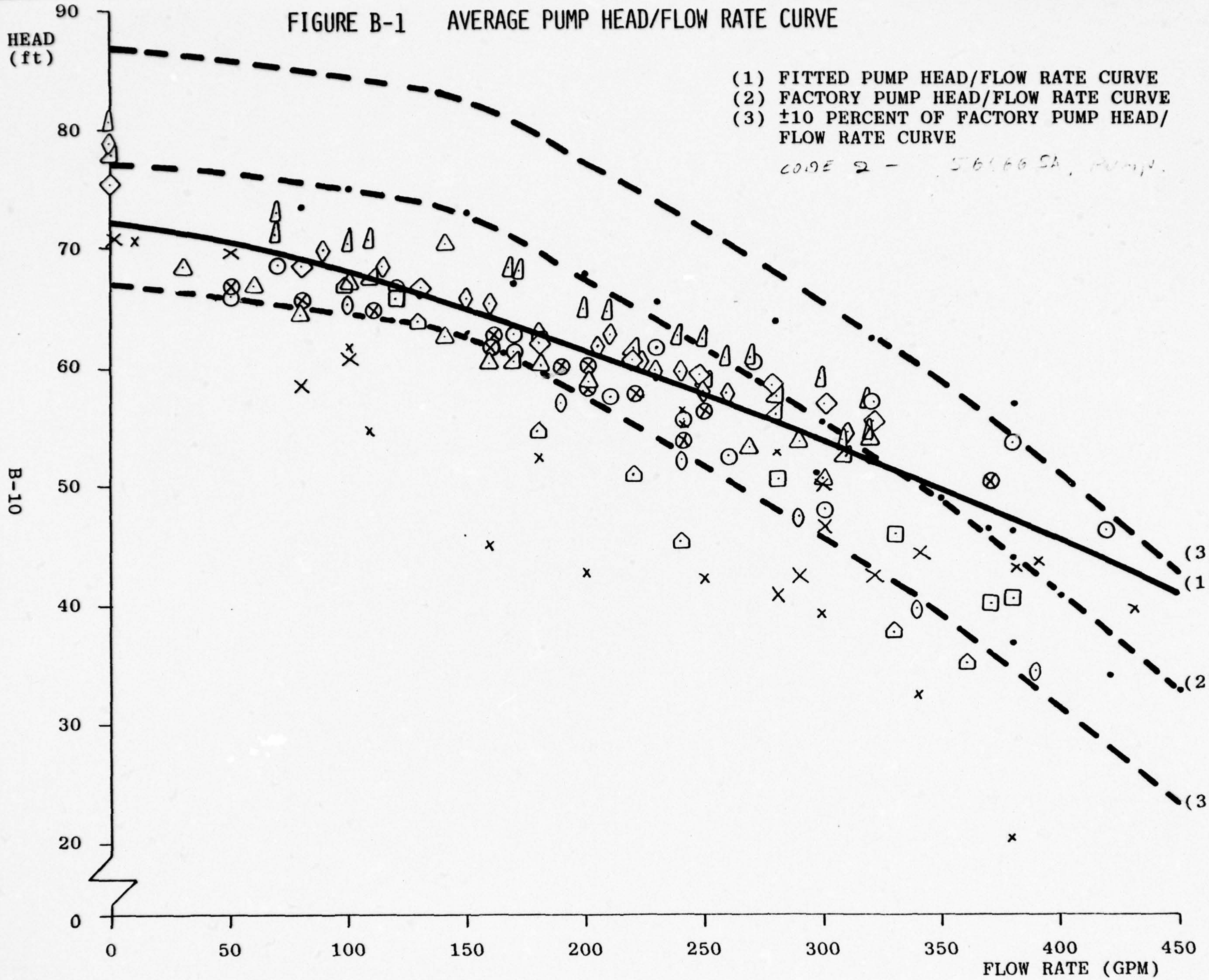


FIGURE B-1 AVERAGE PUMP HEAD/FLOW RATE CURVE

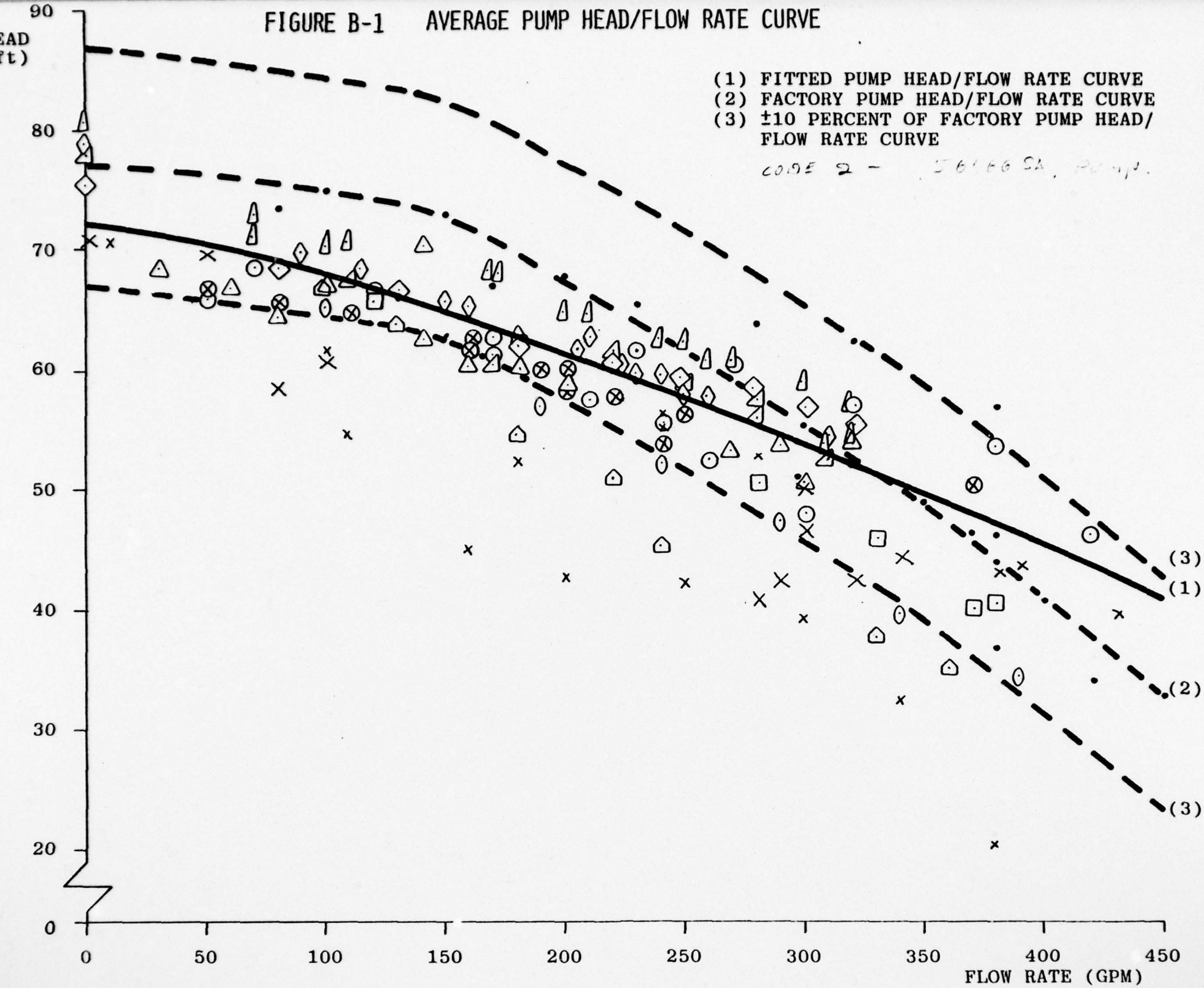
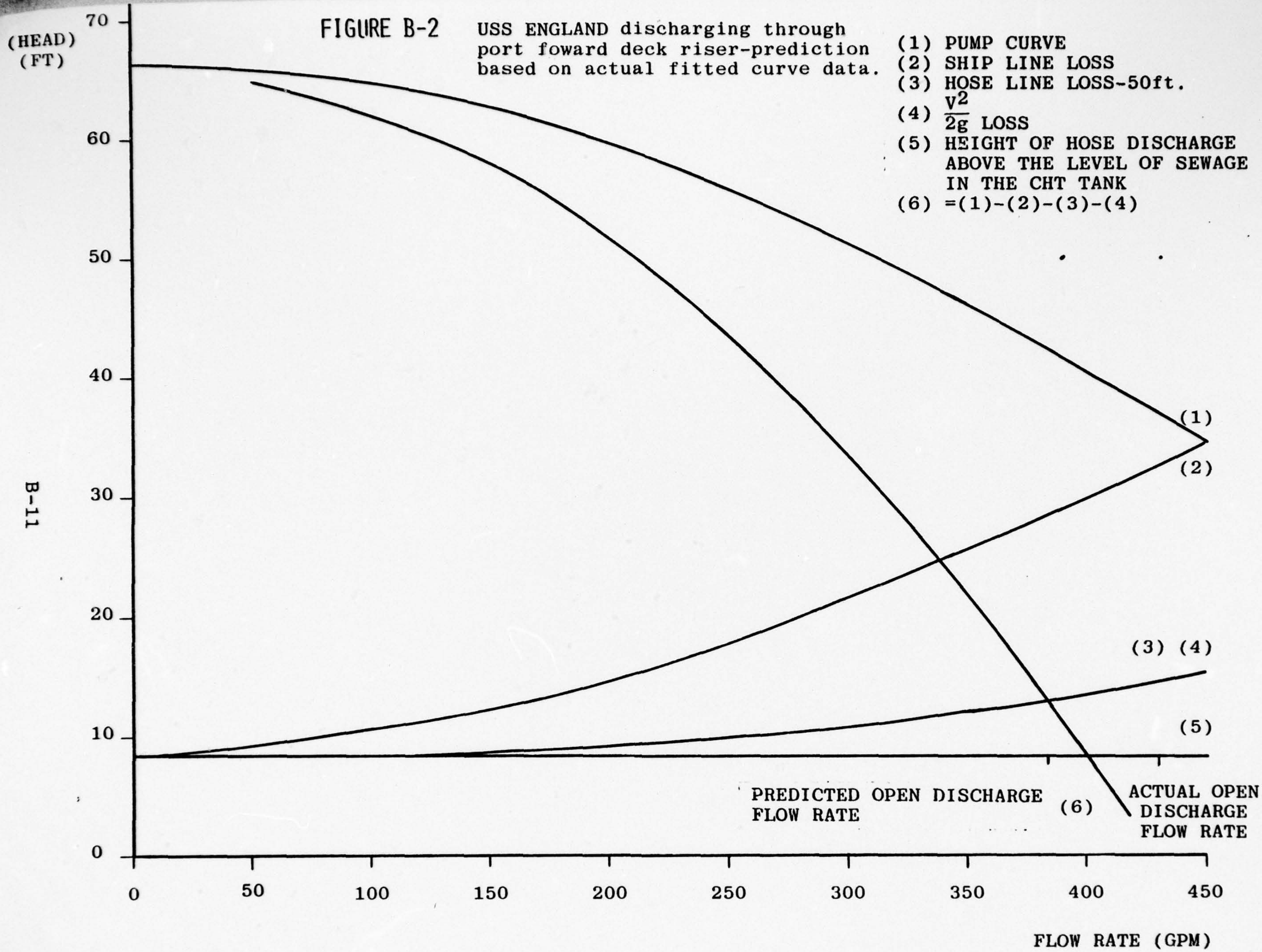


FIGURE B-2 USS ENGLAND discharging through port foward deck riser-prediction based on actual fitted curve data.



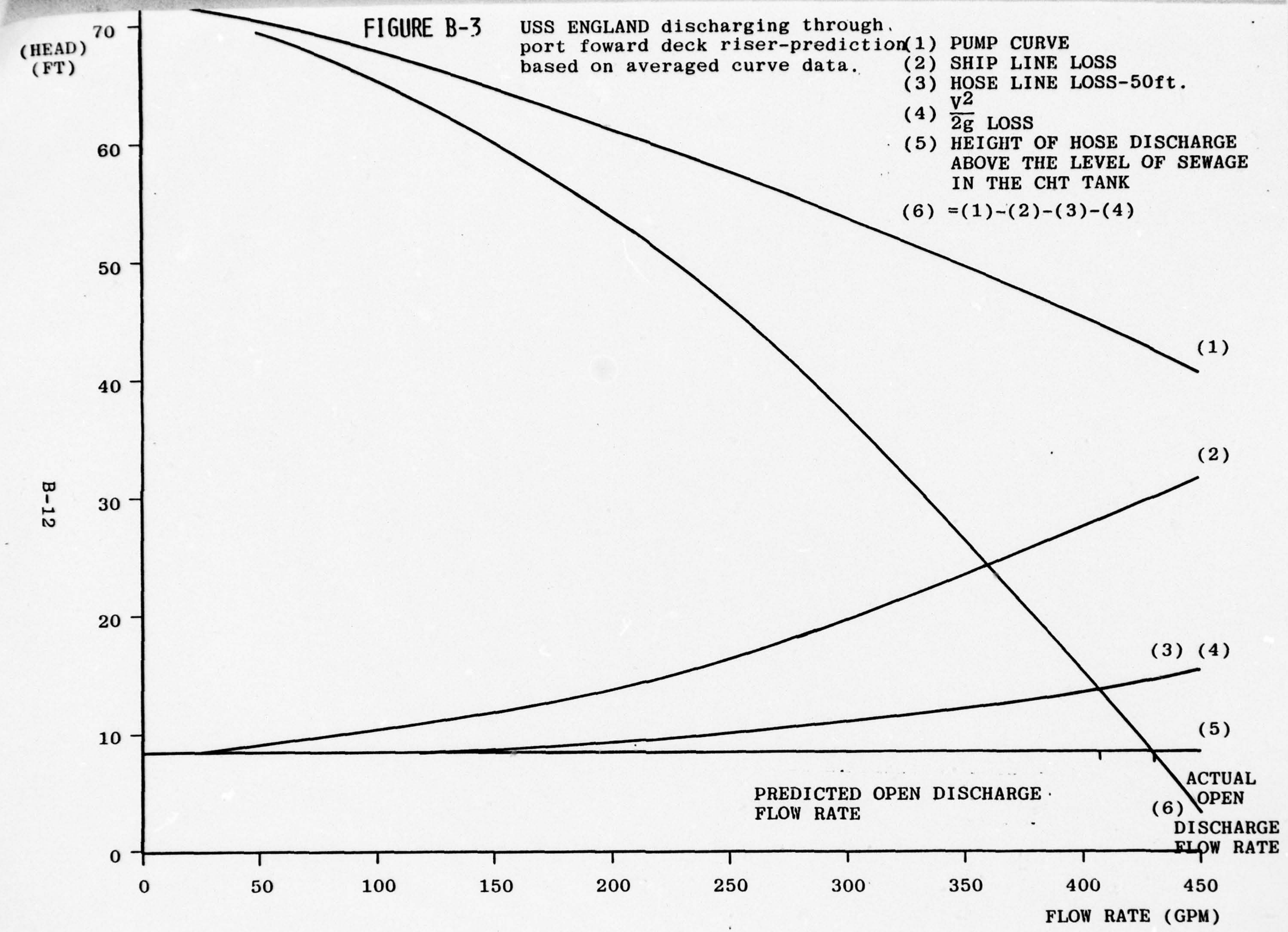


FIGURE B-3
USS ENGLAND discharging through port foward deck riser-prediction based on averaged curve data.
(1) PUMP CURVE
(2) SHIP LINE LOSS
(3) HOSE LINE LOSS-50ft.
(4) $\frac{V^2}{2g}$ LOSS
(5) HEIGHT OF HOSE DISCHARGE ABOVE THE LEVEL OF SEWAGE IN THE CHT TANK
(6) =(1)-(2)-(3)-(4)
(HEAD) (FT)
70
60
50
40
30
20
10
0
FLOW RATE (GPM)
0
50
100
150
200
250
300
350
400
450
(1)
(2)
(3) (4)
(5)
(6)
PREDICTED OPEN DISCHARGE FLOW RATE
ACTUAL OPEN DISCHARGE FLOW RATE

FIGURE B-4 USS ENGLAND discharging through starboard foward deck riser-prediction based on actual fitted curve data.

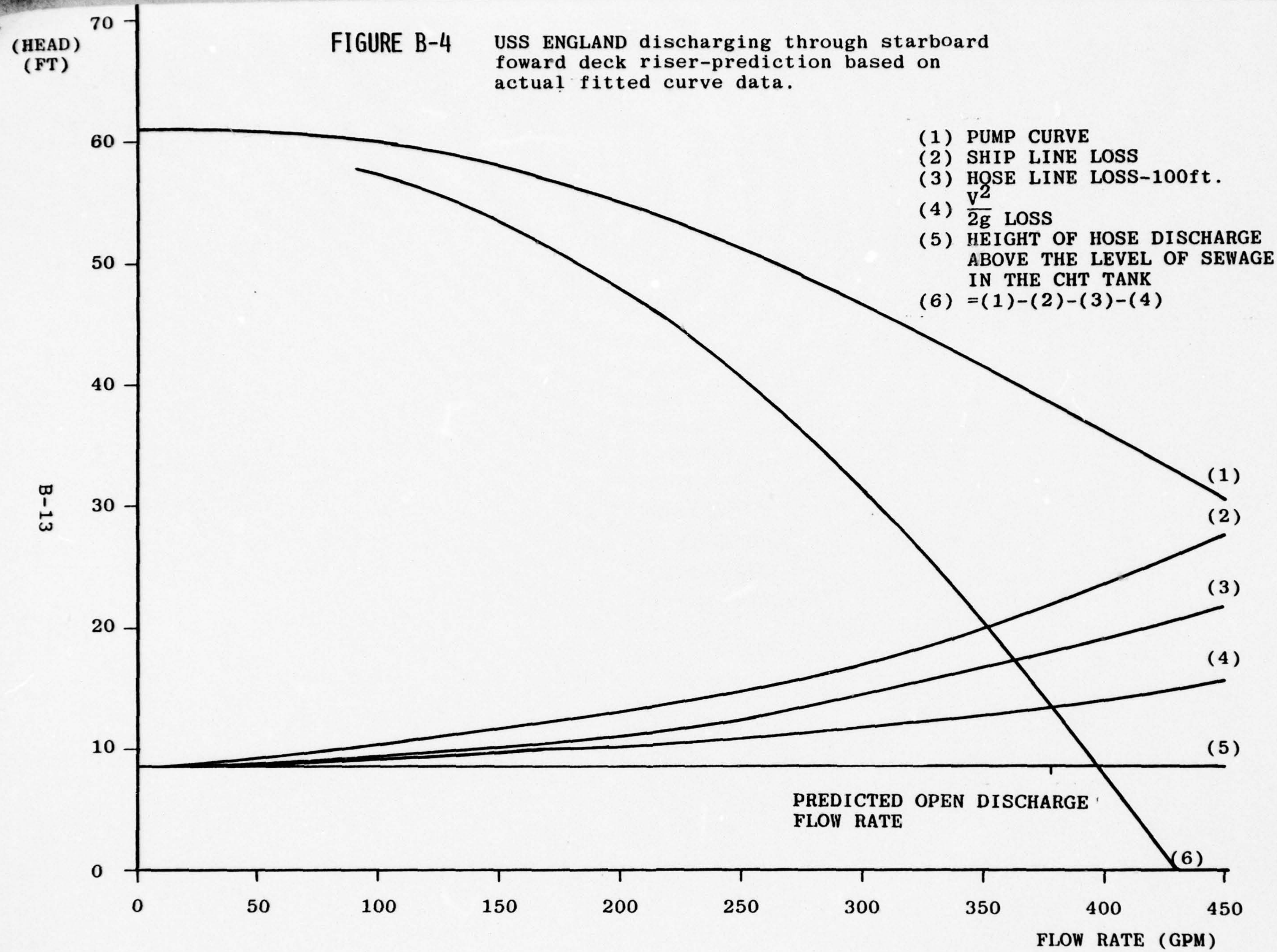
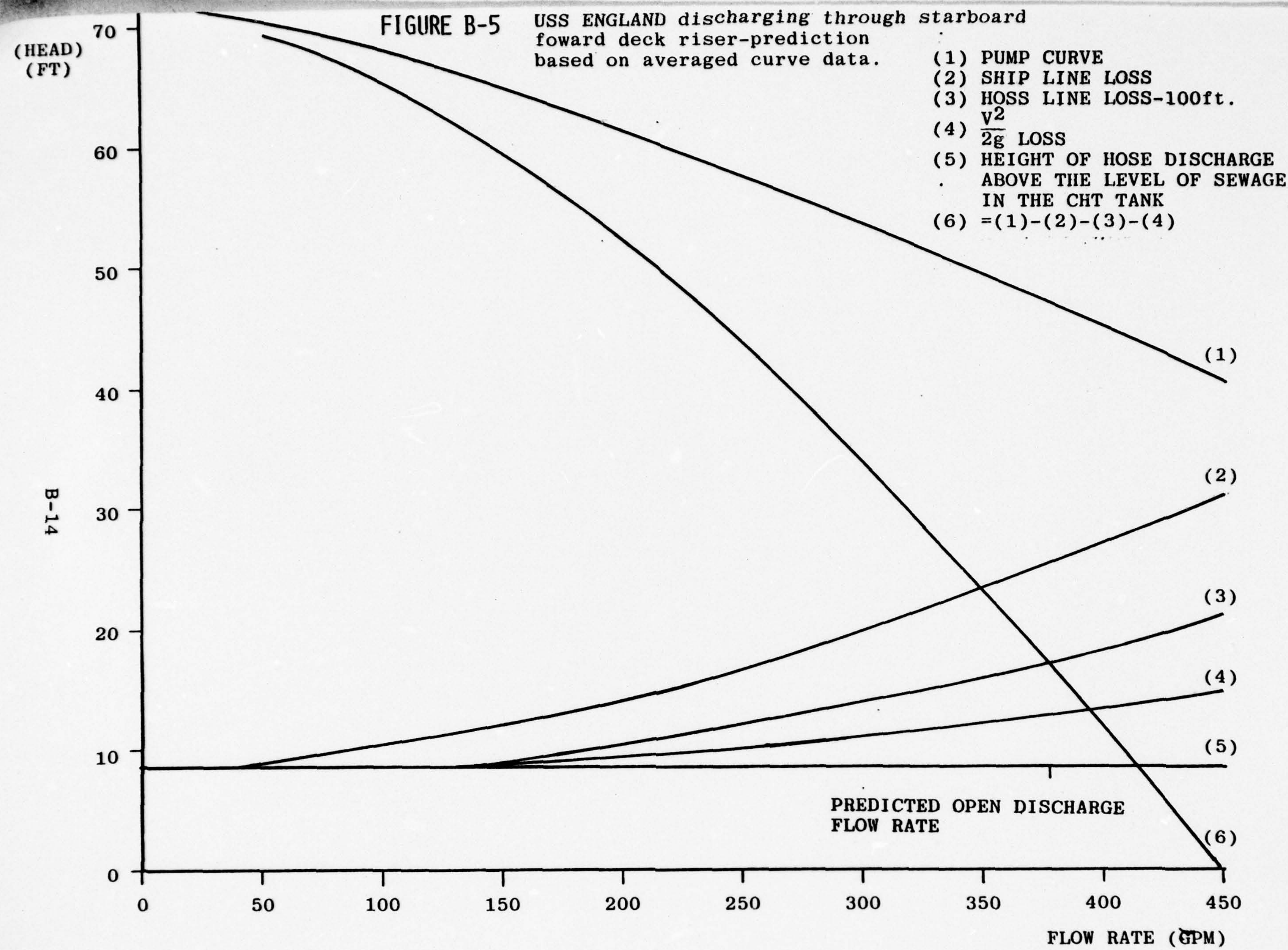


FIGURE B-5 USS ENGLAND discharging through starboard foward deck riser-prediction based on averaged curve data.



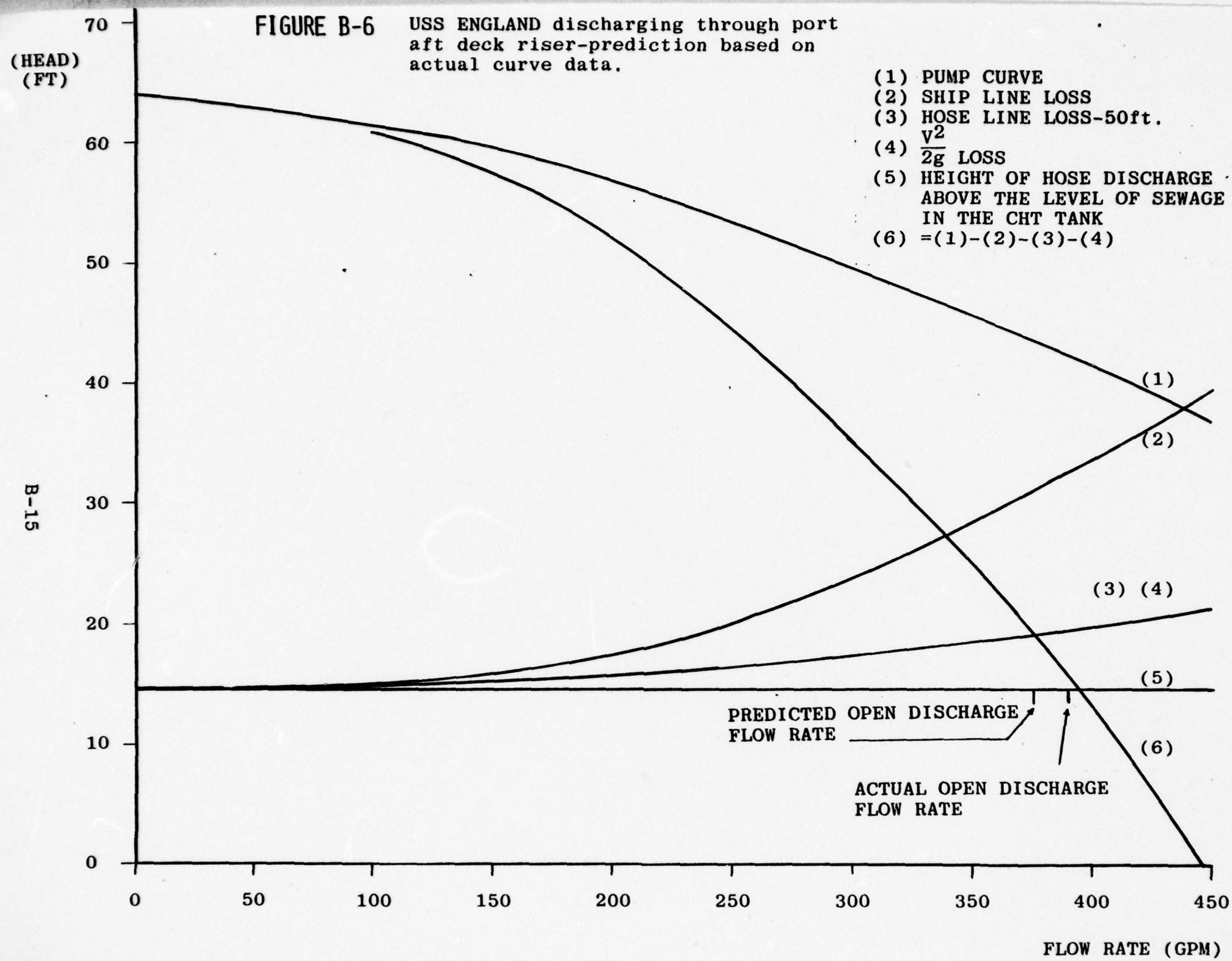


FIGURE B-6 USS ENGLAND discharging through port aft deck riser-prediction based on actual curve data.

FIGURE B-7 USS ENGLAND discharging through port aft deck riser-prediction based on averaged curve data.

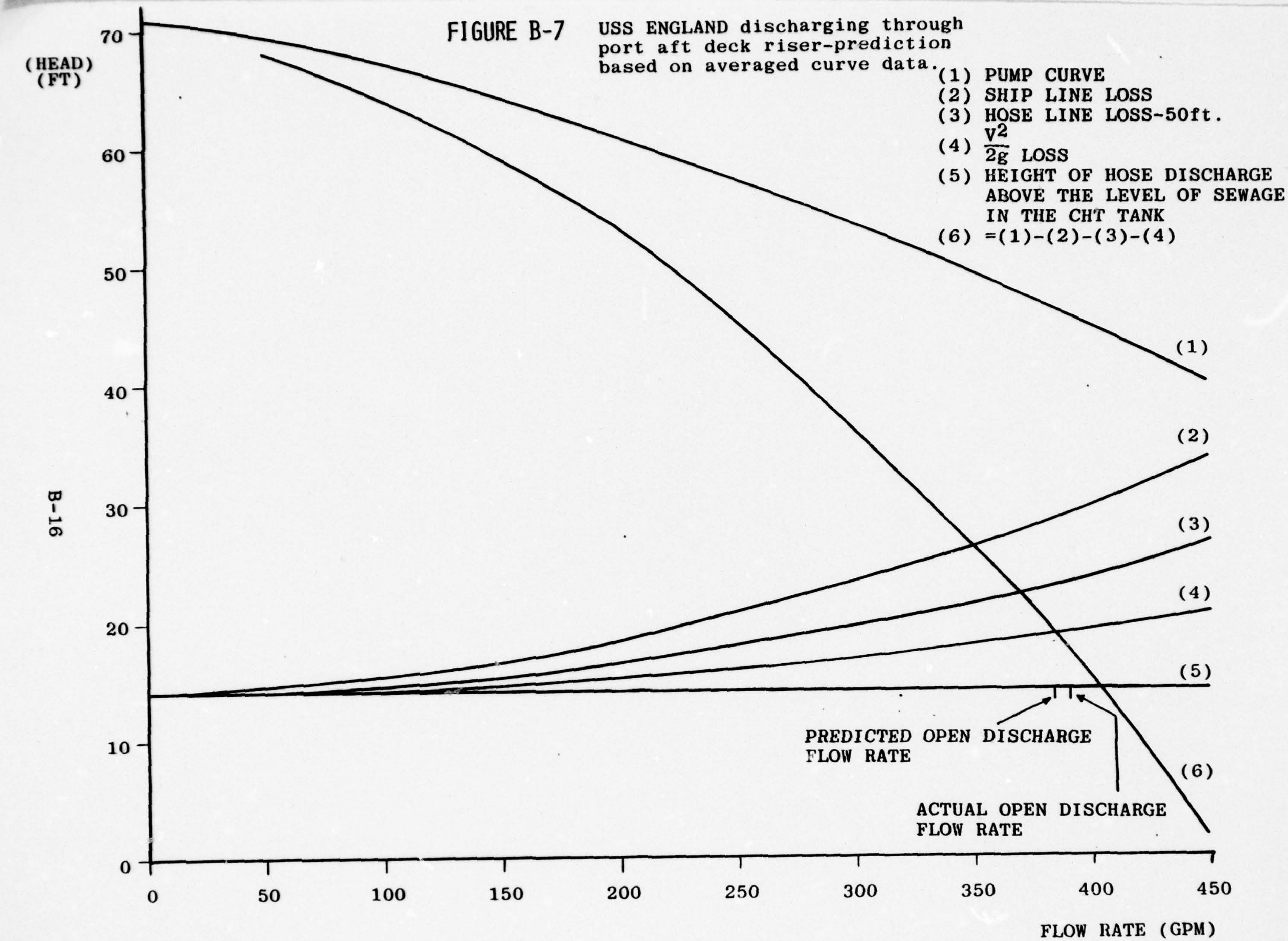
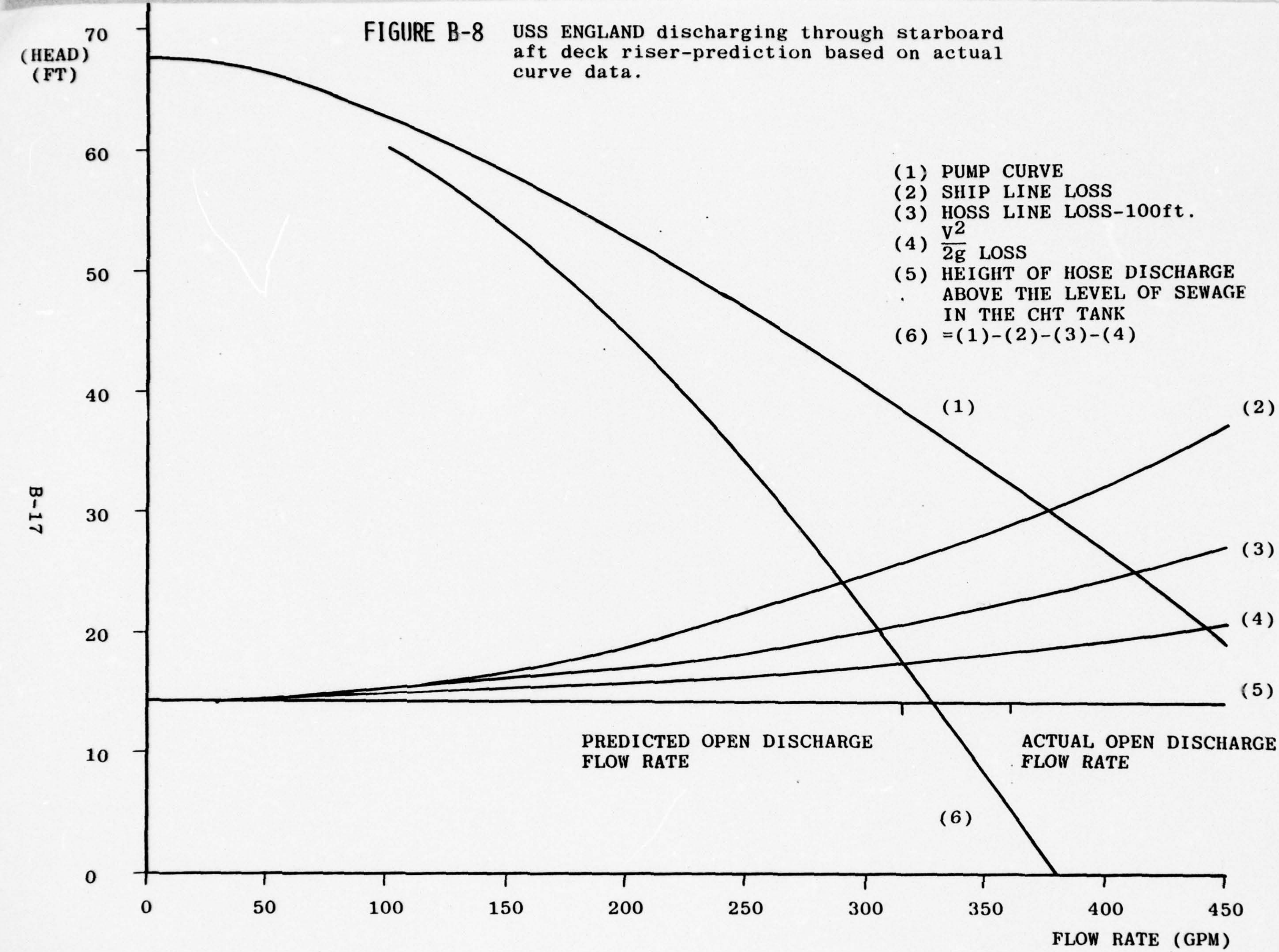


FIGURE B-8 USS ENGLAND discharging through starboard aft deck riser-prediction based on actual curve data.



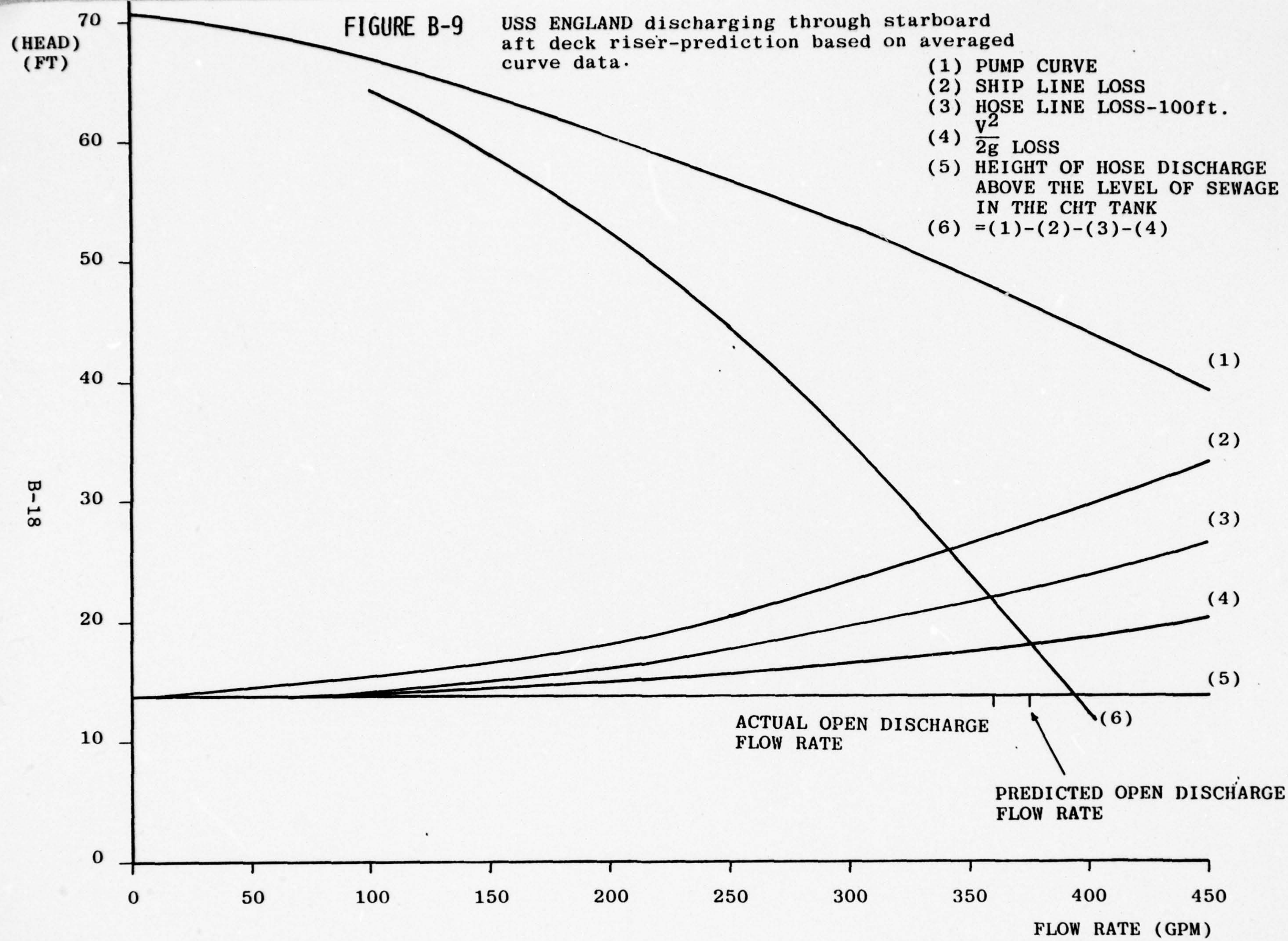


FIGURE B-9 USS ENGLAND discharging through starboard aft deck riser-prediction based on averaged curve data.

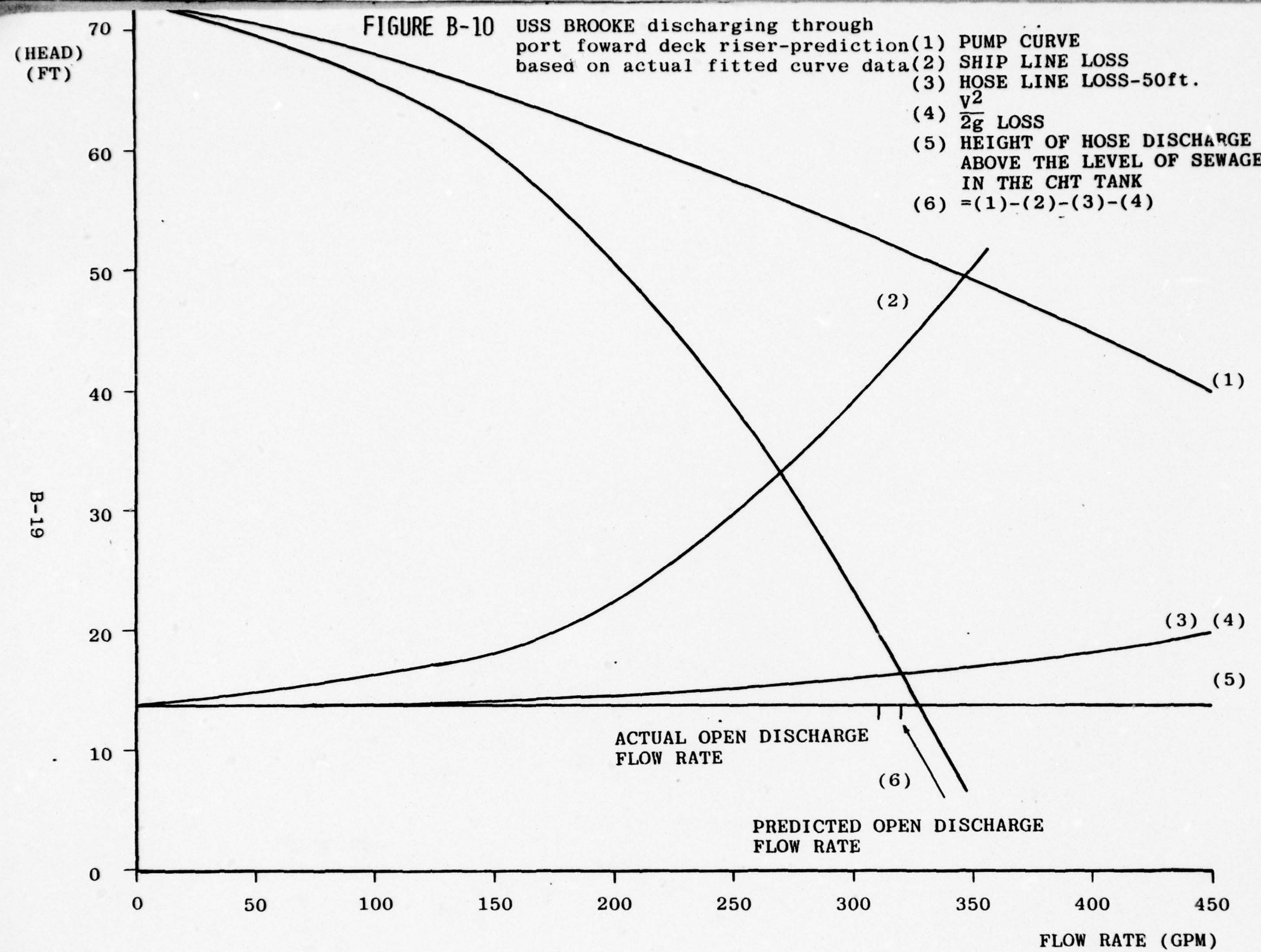
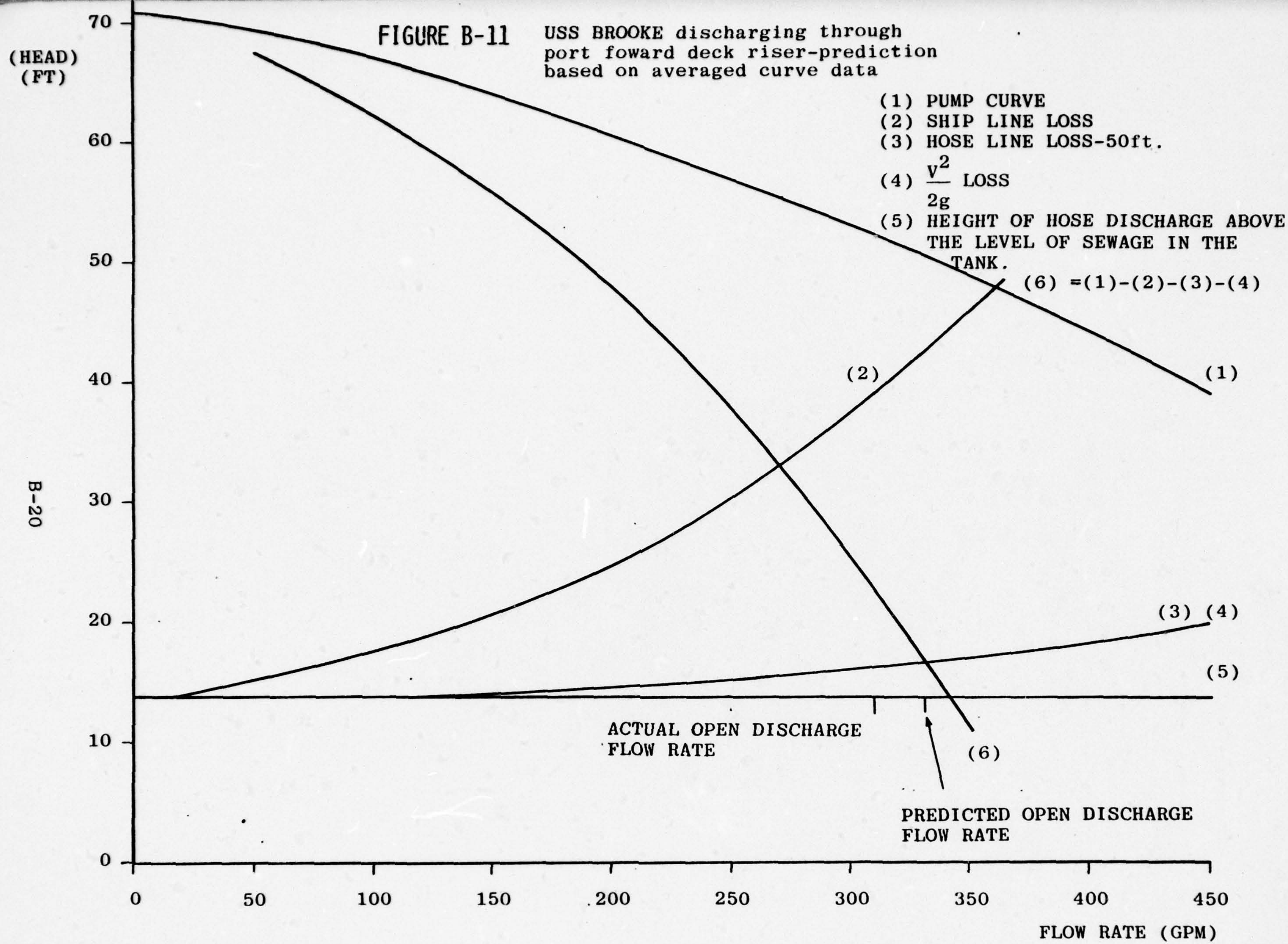


FIGURE B-10 USS BROOKE discharging through port foward deck riser-prediction based on actual fitted curve data

FIGURE B-11 USS BROOKE discharging through port foward deck riser-prediction based on averaged curve data



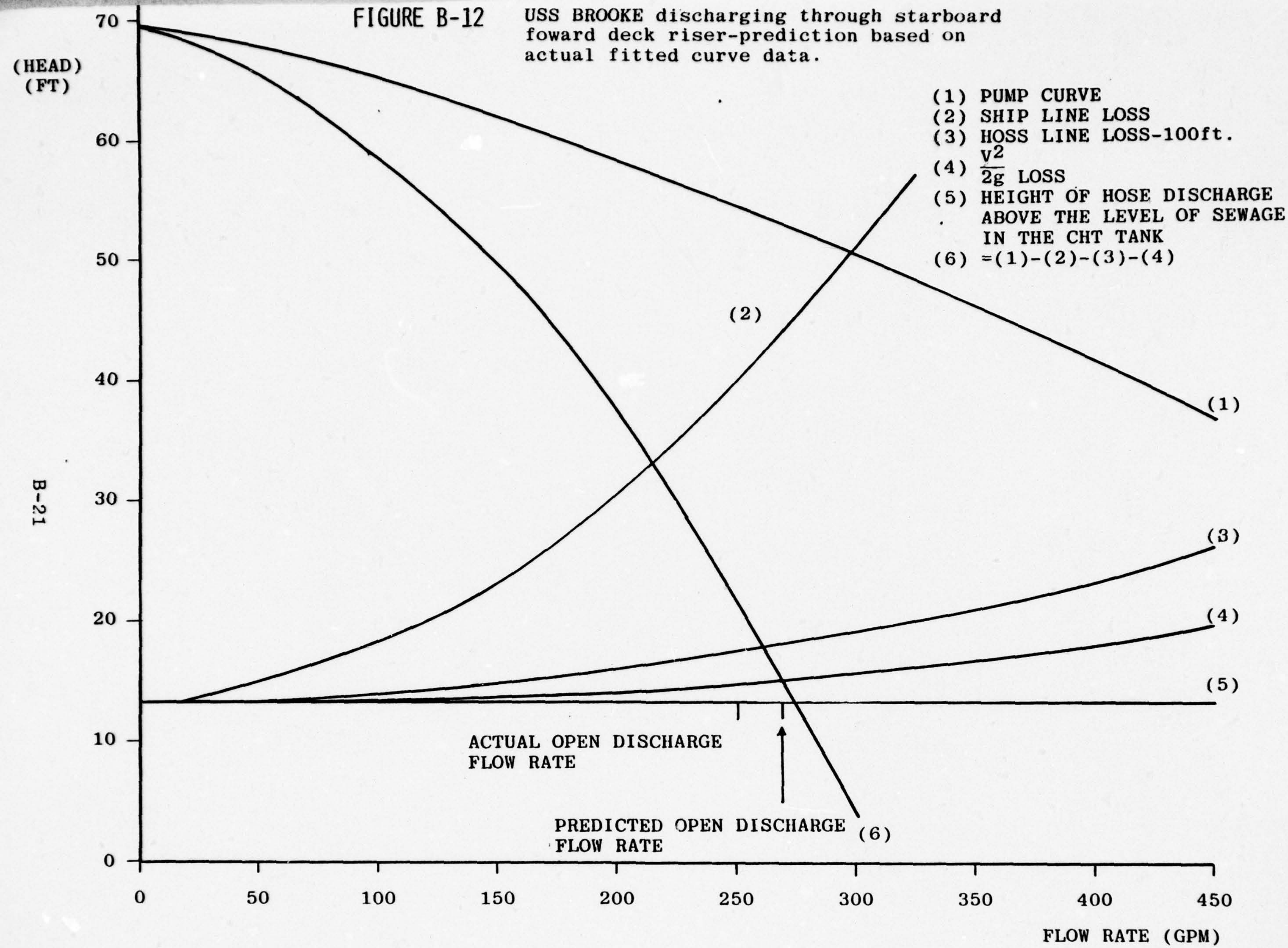


FIGURE B-12 USS BROOKE discharging through starboard foward deck riser-prediction based on actual fitted curve data.

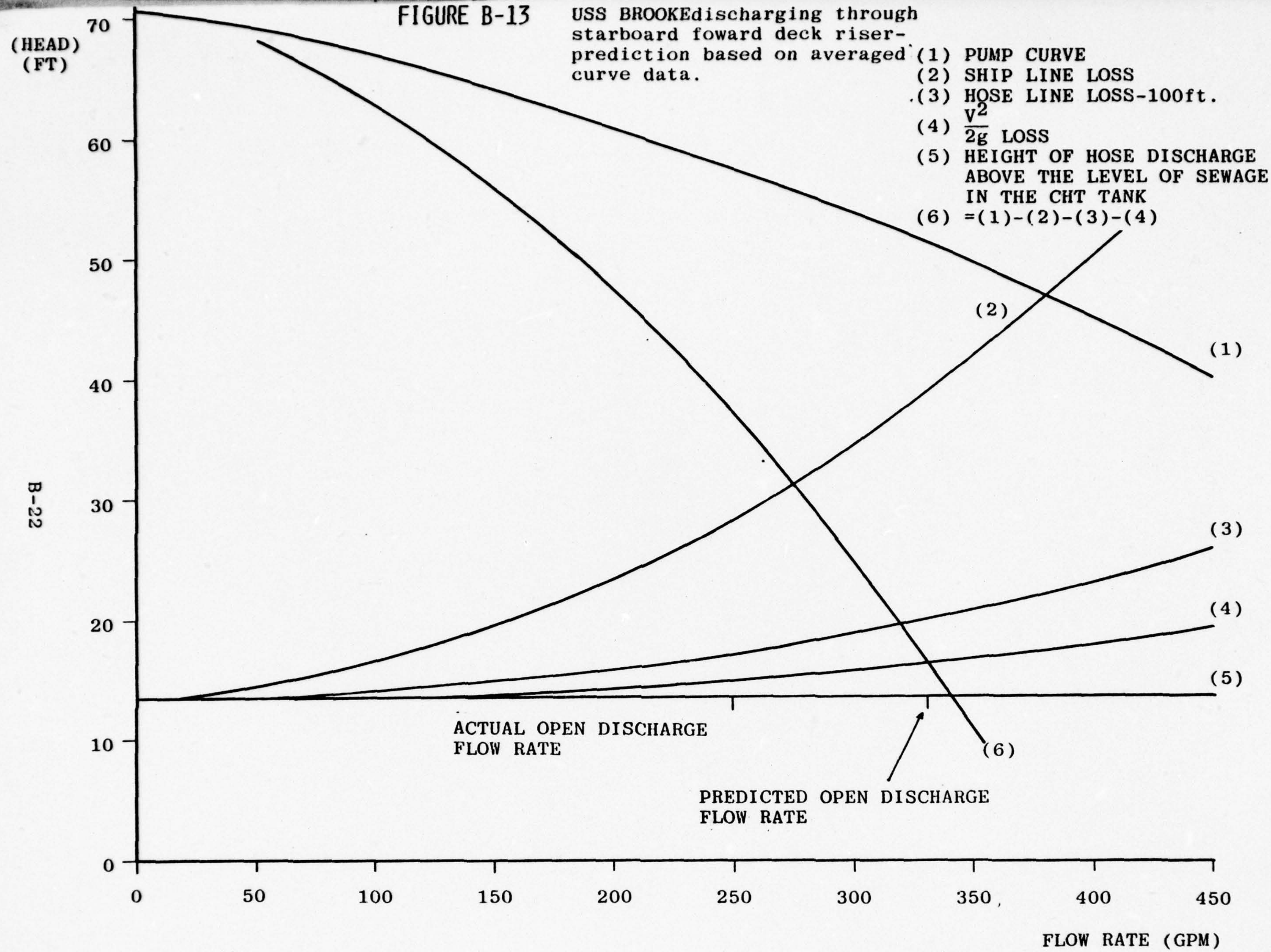


FIGURE B-13 USS BROOKEdischarging through starboard foward deck riser-prediction based on averaged curve data.

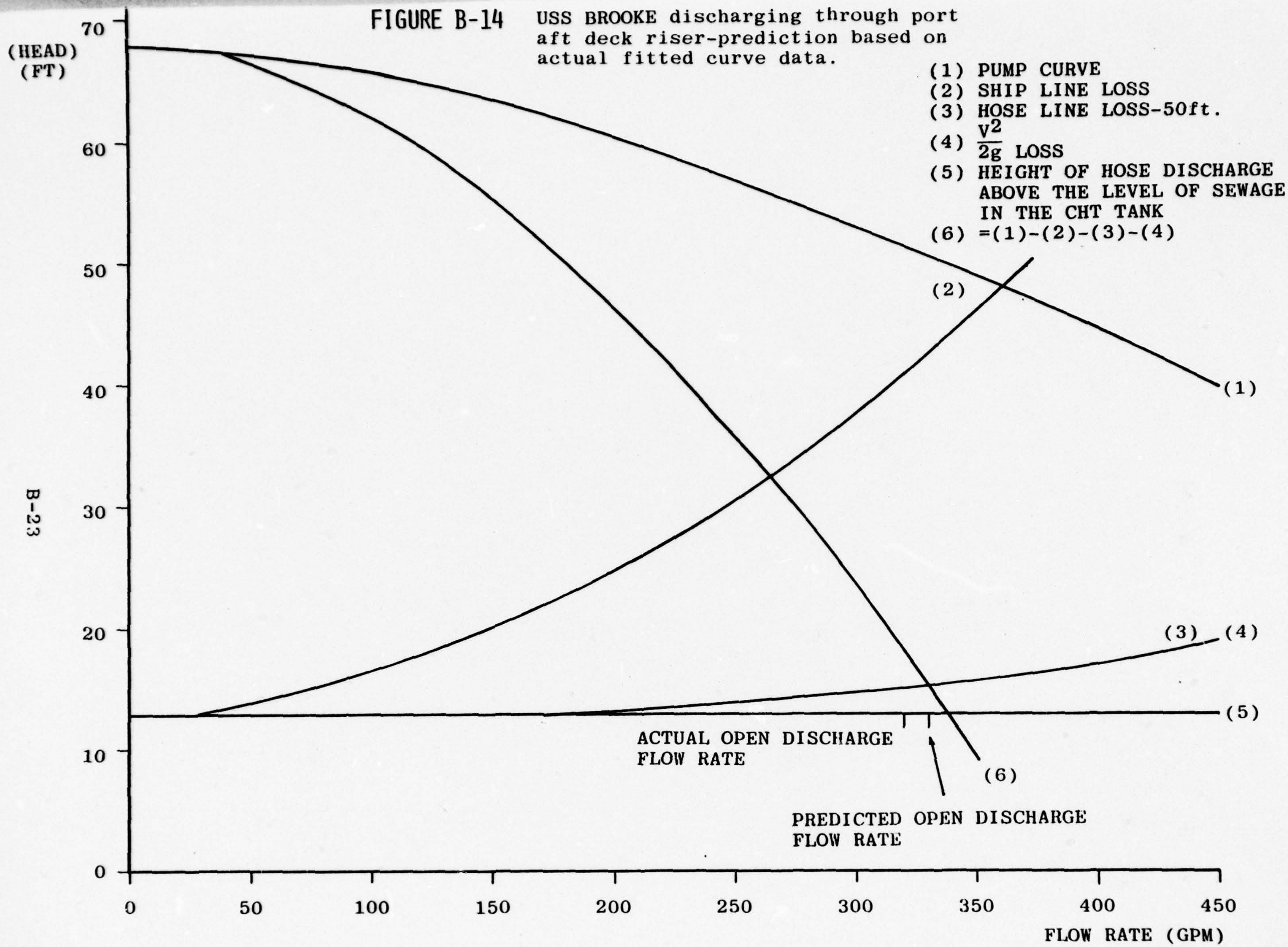


FIGURE B-14 USS BROOKE discharging through port aft deck riser-prediction based on actual fitted curve data.

FIGURE B-15 USS BROOKE discharging through port aft deck riser-predition based on averaged curve data.

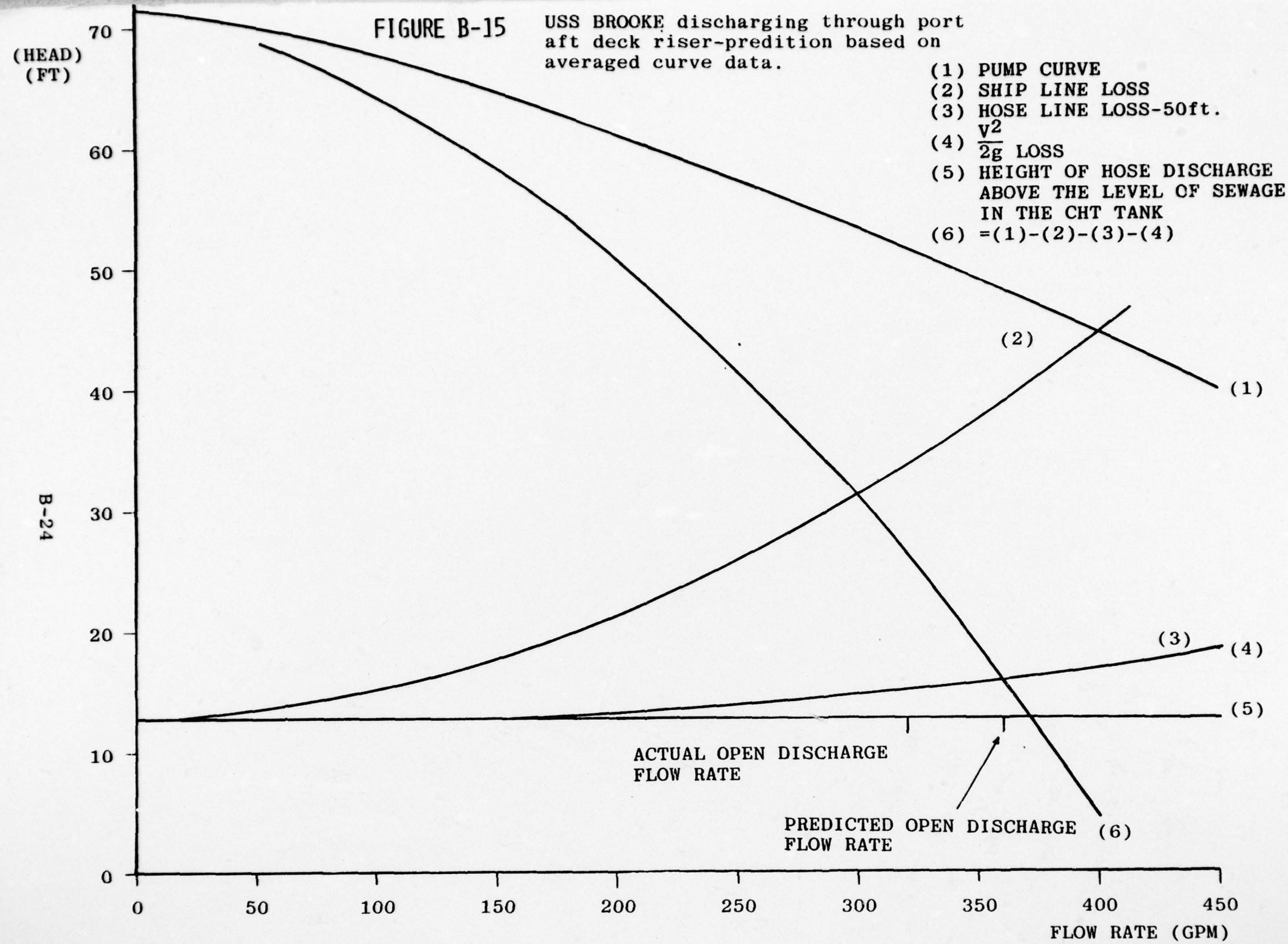
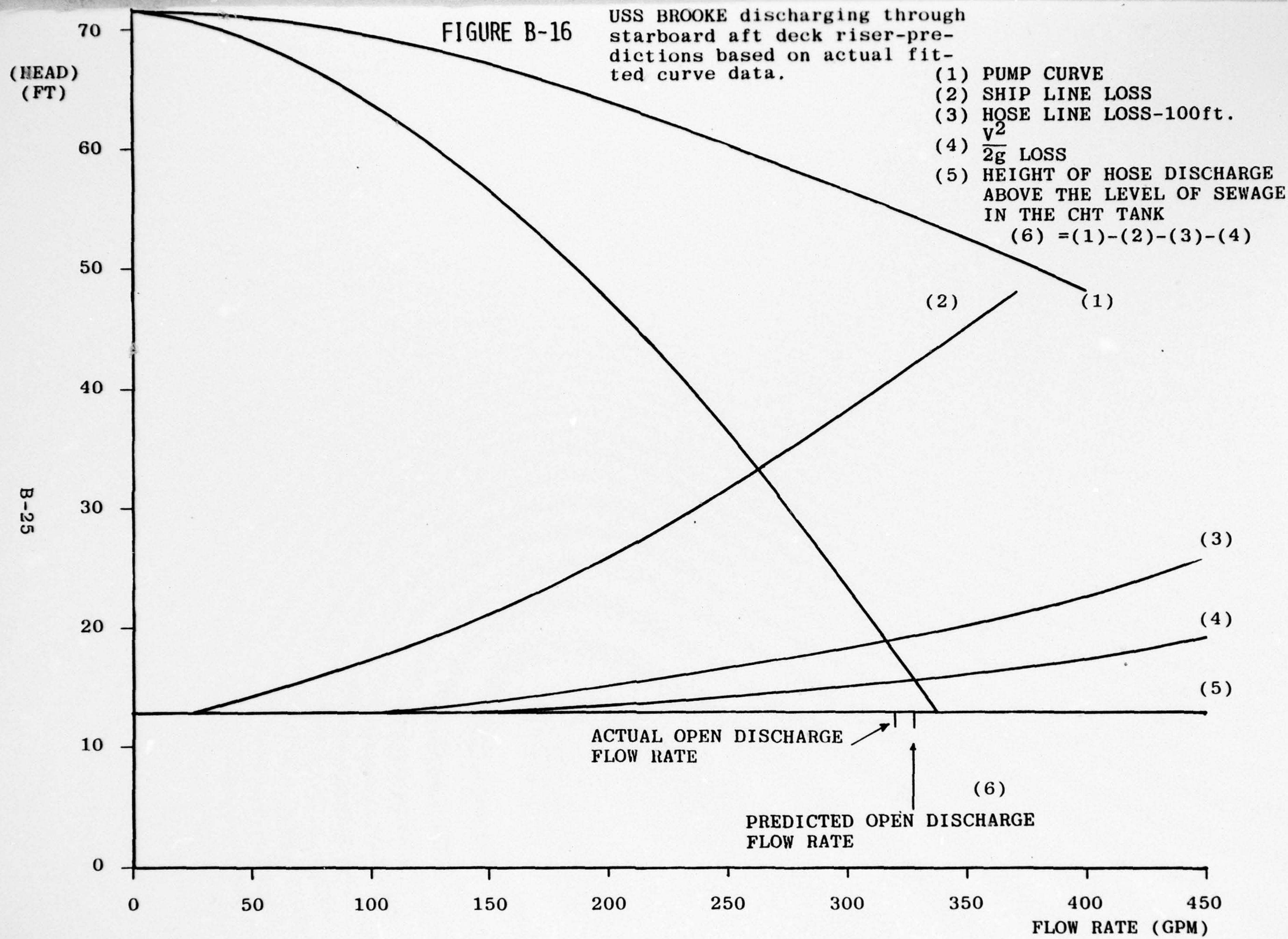


FIGURE B-16



USS BROOKE discharging through starboard aft deck riser-predictions based on actual fitted curve data.
(1) PUMP CURVE
(2) SHIP LINE LOSS
(3) HOSE LINE LOSS-100ft.
(4) $\frac{V^2}{2g}$ LOSS
(5) HEIGHT OF HOSE DISCHARGE ABOVE THE LEVEL OF SEWAGE IN THE CHT TANK
(6) =(1)-(2)-(3)-(4)
(HEAD) (FT)
70
60
50
40
30
20
10
0
(1)
(2)
(3)
(4)
(5)
(6)
ACTUAL OPEN DISCHARGE FLOW RATE
PREDICTED OPEN DISCHARGE FLOW RATE
0
50
100
150
200
250
300
350
400
450
FLOW RATE (GPM)

FIGURE B-17 USS BROOKE discharging through starboard aft deck riser-prediction based on averaged curve data

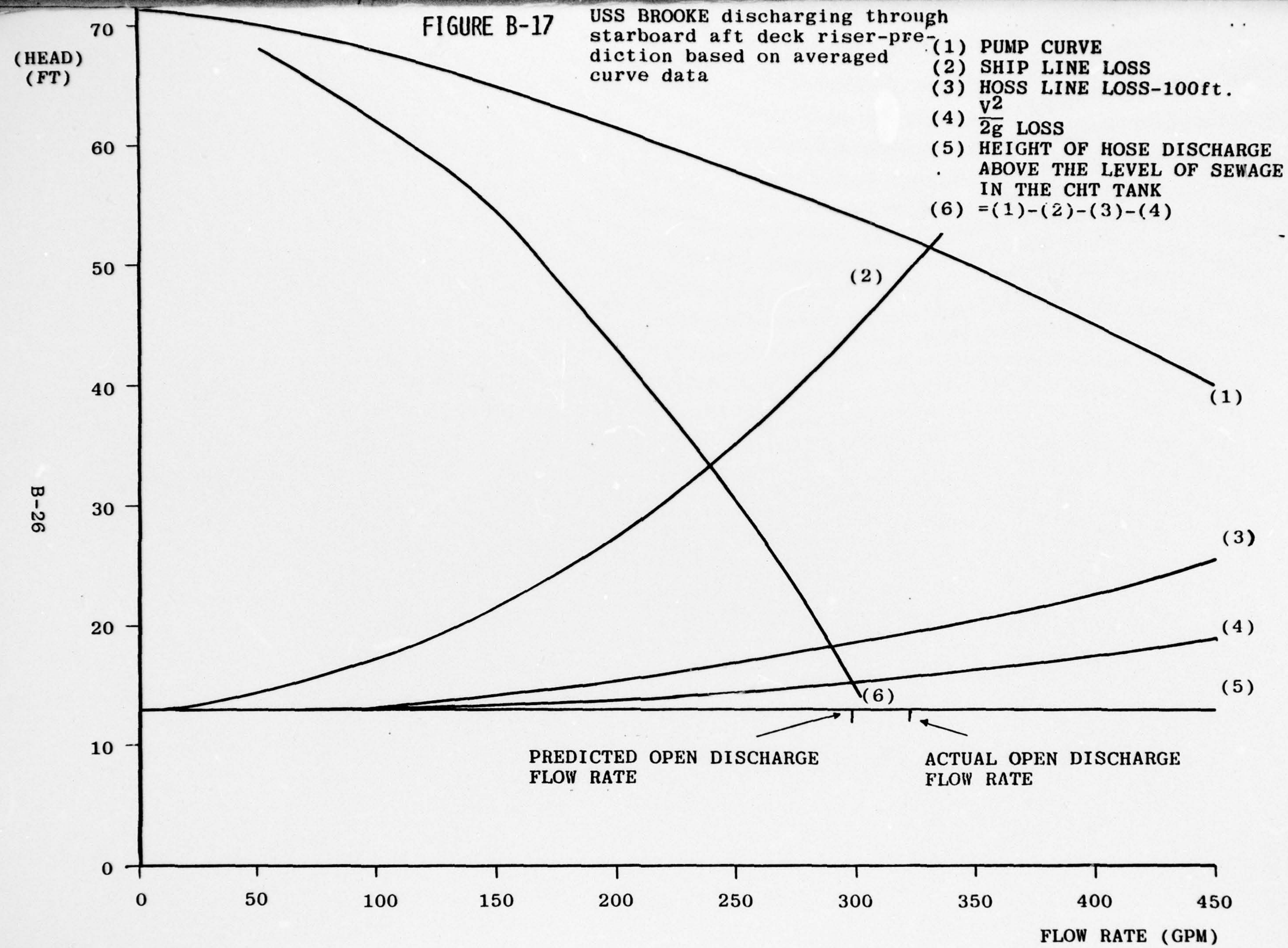


FIGURE B-18 USS ROARKE discharging through port aft deck riser-prediction based on actual fitted curve data.

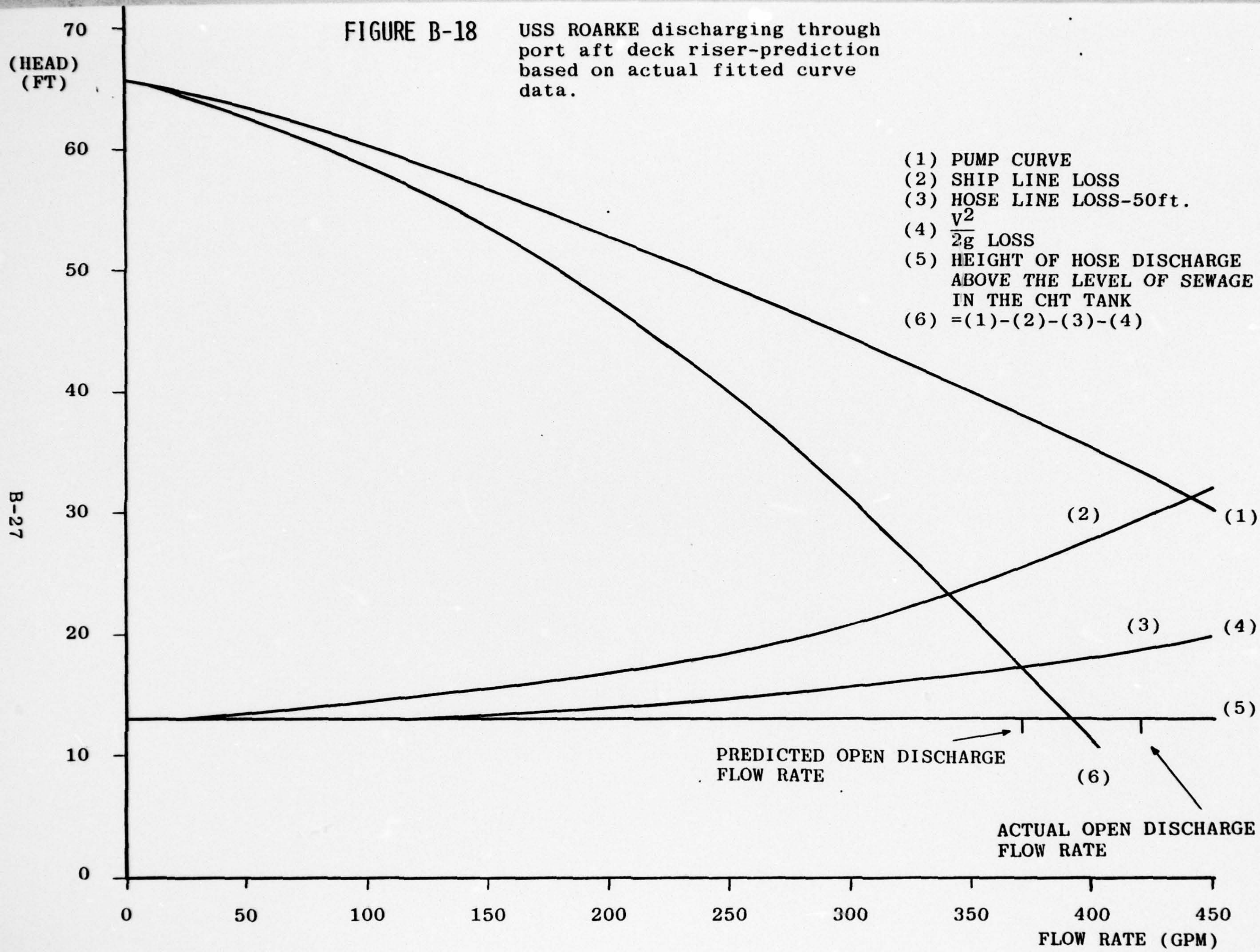
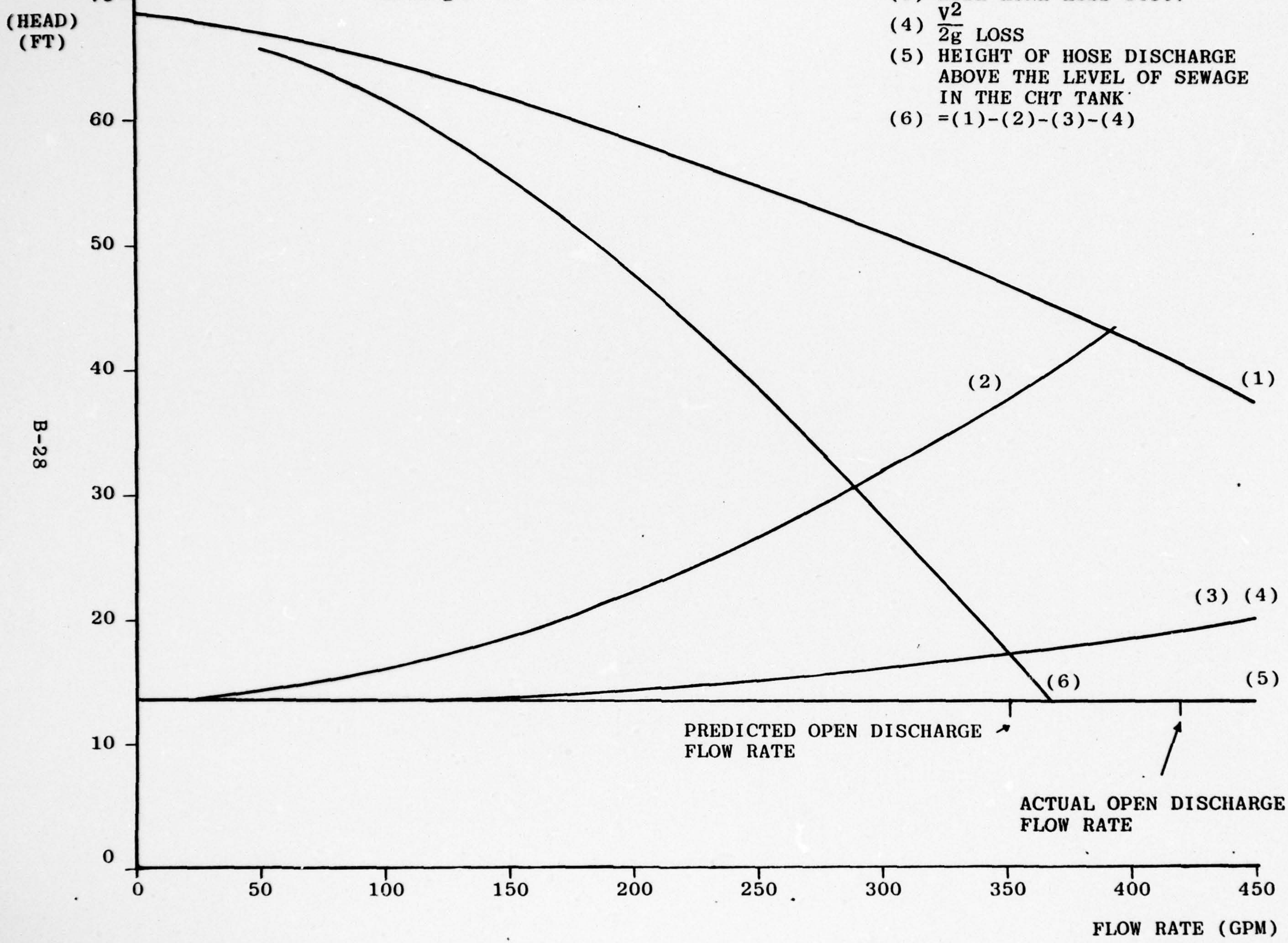


FIGURE B-19 USS ROARKE discharging through port aft deck riser-prediction based on averaged curve data.



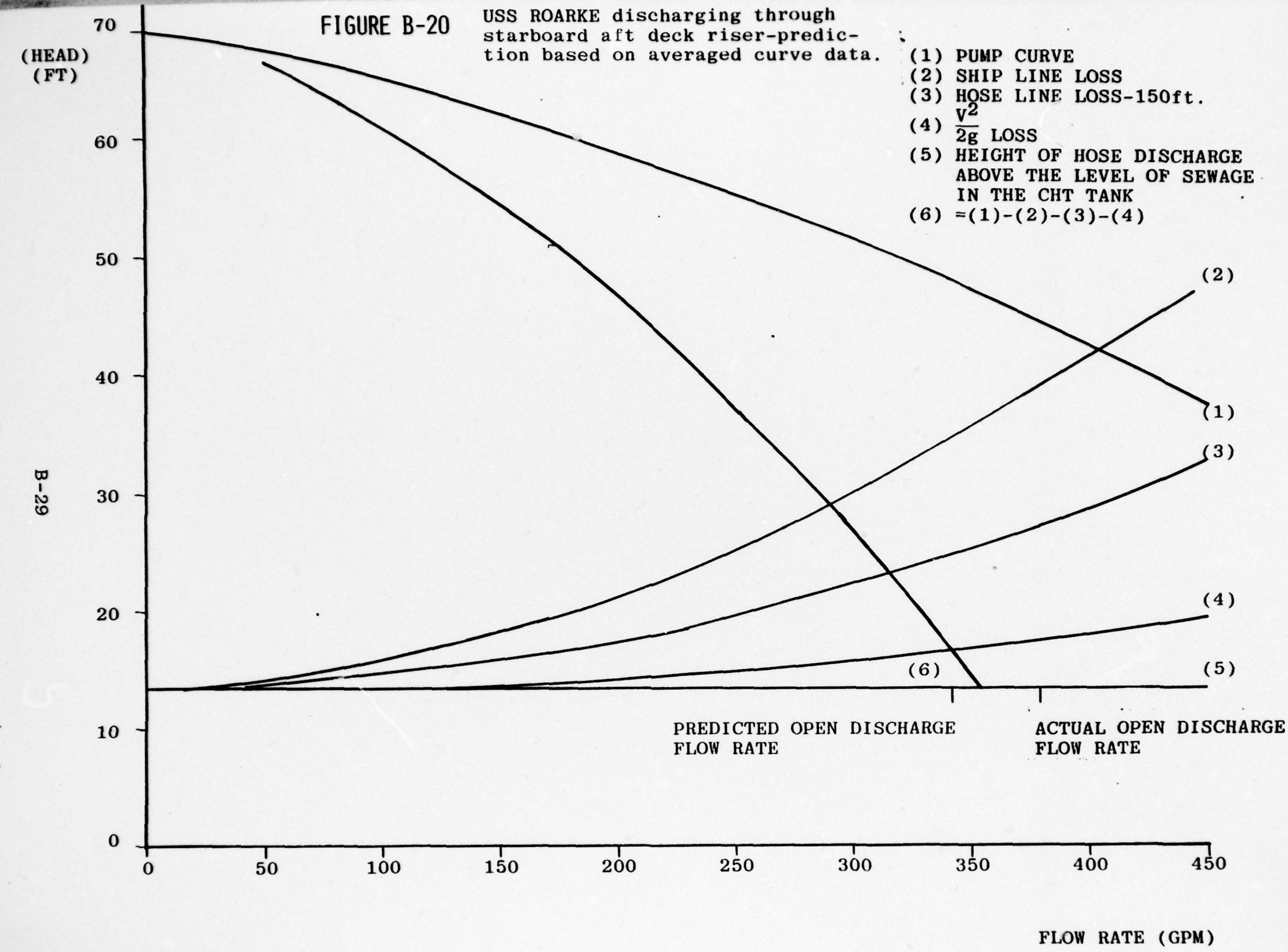


FIGURE B-20
USS ROARKE discharging through starboard aft deck riser-prediction based on averaged curve data.
(1) PUMP CURVE
(2) SHIP LINE LOSS
(3) HOSE LINE LOSS-150ft.
(4) $\frac{V^2}{2g}$ LOSS
(5) HEIGHT OF HOSE DISCHARGE ABOVE THE LEVEL OF SEWAGE IN THE CHT TANK
(6) =(1)-(2)-(3)-(4)
(HEAD) (FT)
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
(1)
(2)
(3)
(4)
(5)
(6)
PREDICTED OPEN DISCHARGE FLOW RATE
ACTUAL OPEN DISCHARGE FLOW RATE
FLOW RATE (GPM)

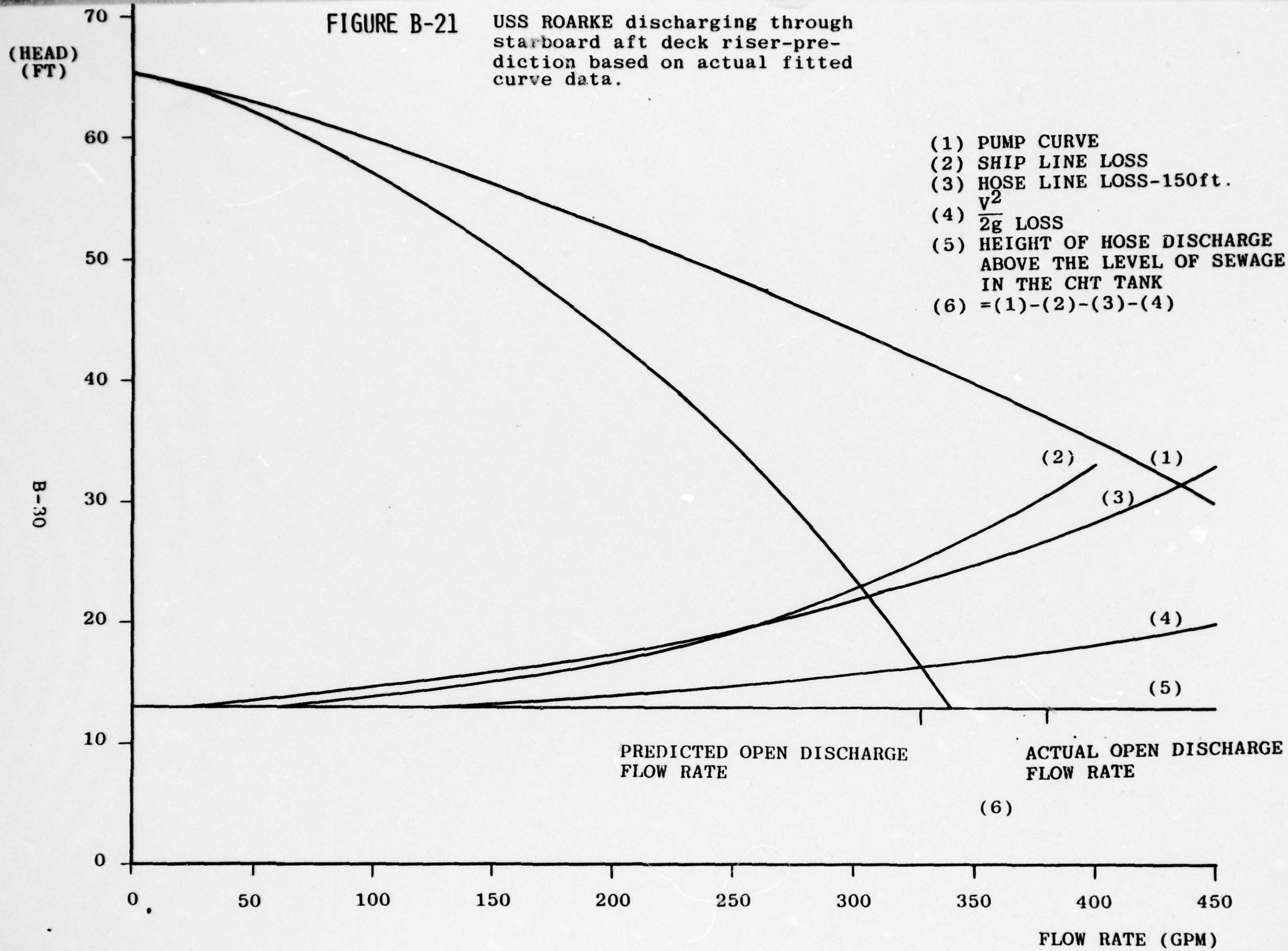
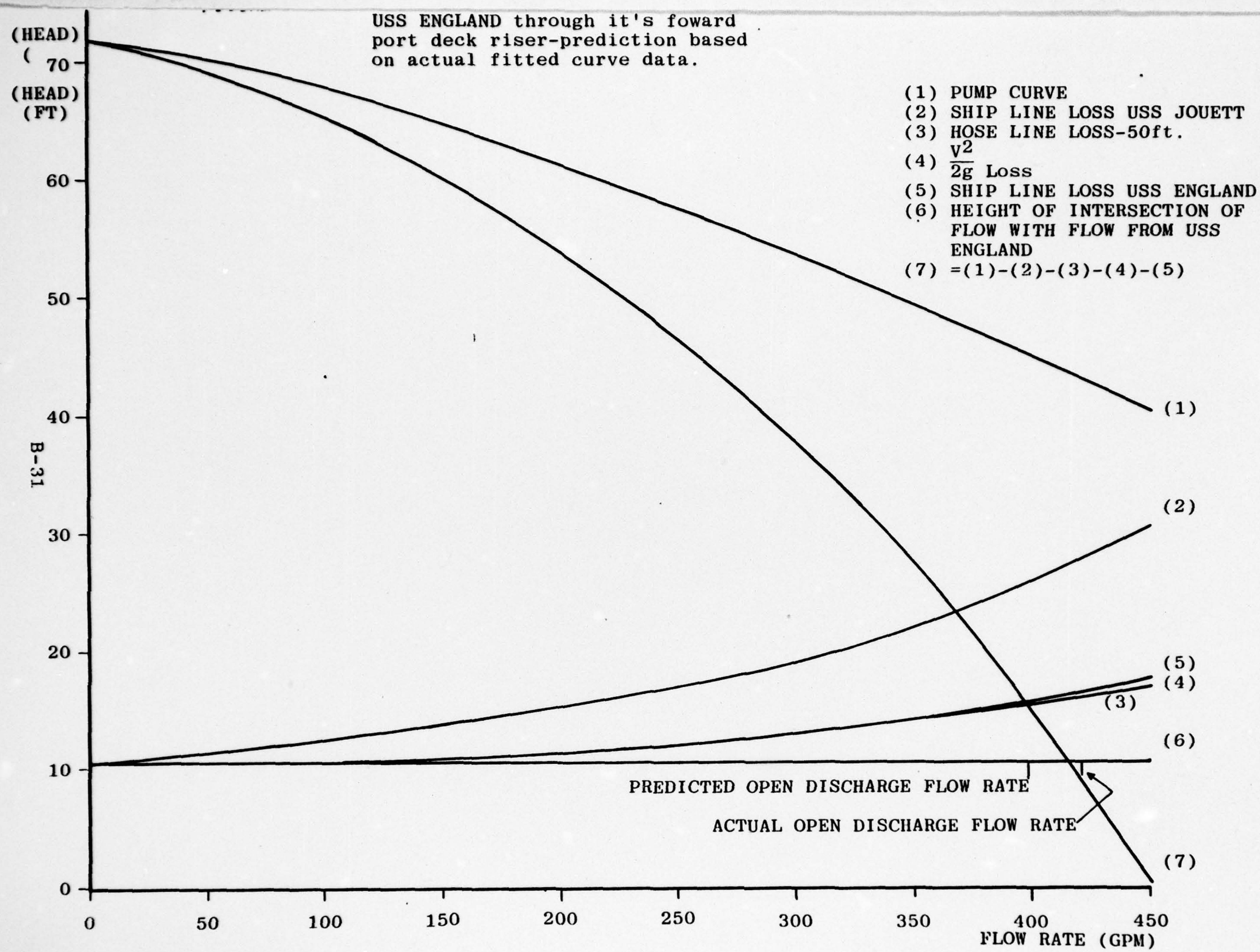
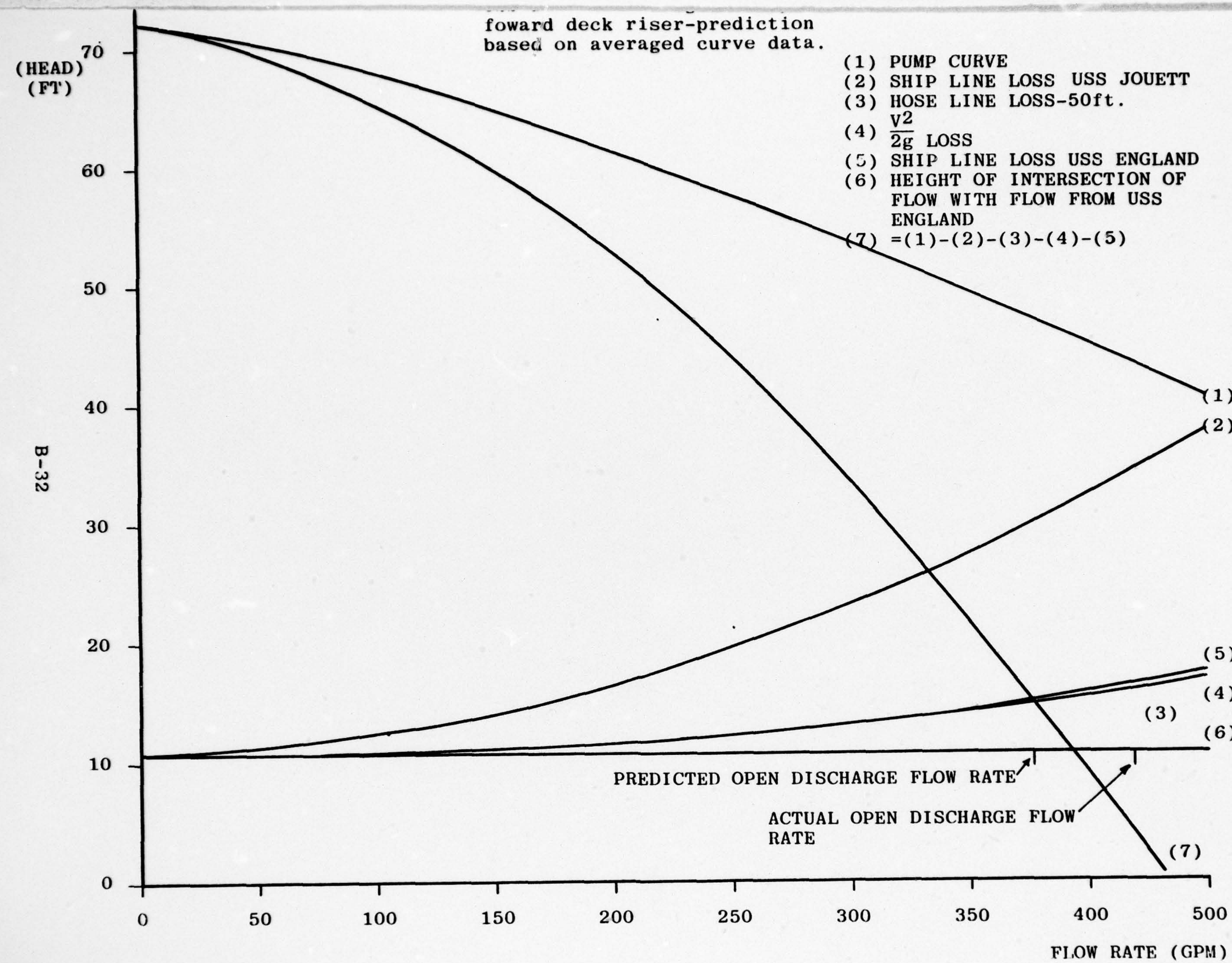
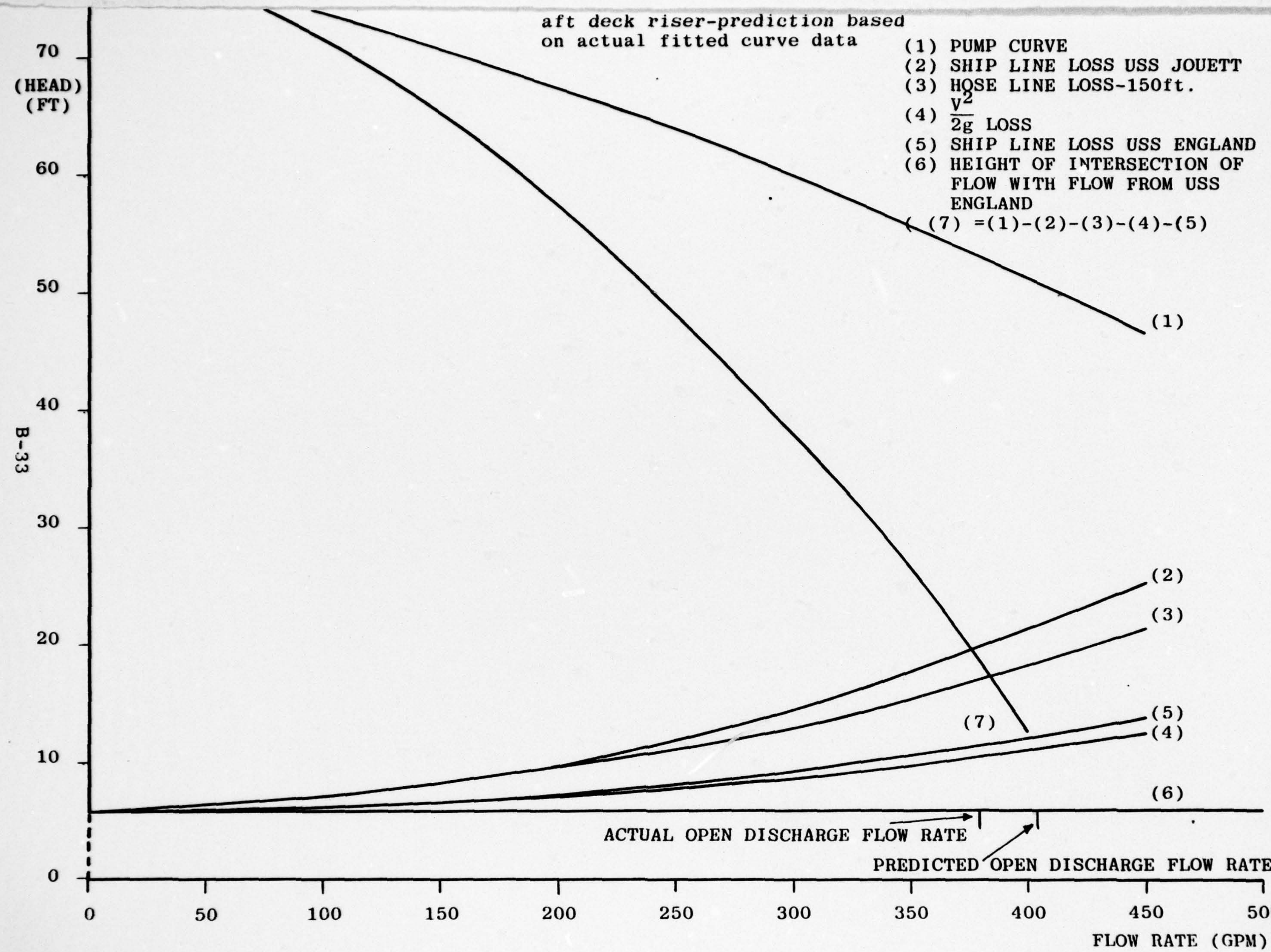


FIGURE B-21 USS ROARKE discharging through starboard aft deck riser-prediction based on actual fitted curve data.



USS ENGLAND through it's foward
port deck riser-prediction based
on actual fitted curve data.
(1) PUMP CURVE
(2) SHIP LINE LOSS USS JOUETT
(3) HOSE LINE LOSS-50ft.
(4) $\frac{V^2}{2g}$ Loss
(5) SHIP LINE LOSS USS ENGLAND
(6) HEIGHT OF INTERSECTION OF FLOW WITH FLOW FROM USS ENGLAND
(7) =(1)-(2)-(3)-(4)-(5)
(HEAD)
(HEAD)
(FT)
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
FLOW RATE (GPM)
(1)
(2)
(5)
(4)
(3)
(6)
(7)
PREDICTED OPEN DISCHARGE FLOW RATE
ACTUAL OPEN DISCHARGE FLOW RATE


foward deck riser-prediction
based on averaged curve data.
(1) PUMP CURVE
(2) SHIP LINE LOSS USS JOUETT
(3) HOSE LINE LOSS-50ft.
(4) $\frac{V^2}{2g}$ LOSS
(5) SHIP LINE LOSS USS ENGLAND
(6) HEIGHT OF INTERSECTION OF FLOW WITH FLOW FROM USS ENGLAND
(7) =(1)-(2)-(3)-(4)-(5)
(HEAD) (FT)
70
60
50
40
30
20
10
0
(1)
(2)
(5)
(4)
(3)
(6)
(7)
PREDICTED OPEN DISCHARGE FLOW RATE
ACTUAL OPEN DISCHARGE FLOW RATE
0
50
100
150
200
250
300
350
400
500
FLOW RATE (GPM)


aft deck riser-prediction based
on actual fitted curve data
(1) PUMP CURVE
(2) SHIP LINE LOSS USS JOUETT
(3) HOSE LINE LOSS-150ft.
(4) $\frac{V^2}{2g}$ LOSS
(5) SHIP LINE LOSS USS ENGLAND
(6) HEIGHT OF INTERSECTION OF FLOW WITH FLOW FROM USS ENGLAND
(7) =(1)-(2)-(3)-(4)-(5)
(HEAD) (FT)
0
10
20
30
40
50
60
70
0
50
100
150
200
250
300
350
400
450
500
FLOW RATE (GPM)
(1)
(2)
(3)
(4)
(5)
(6)
(7)
ACTUAL OPEN DISCHARGE FLOW RATE
PREDICTED OPEN DISCHARGE FLOW RATE

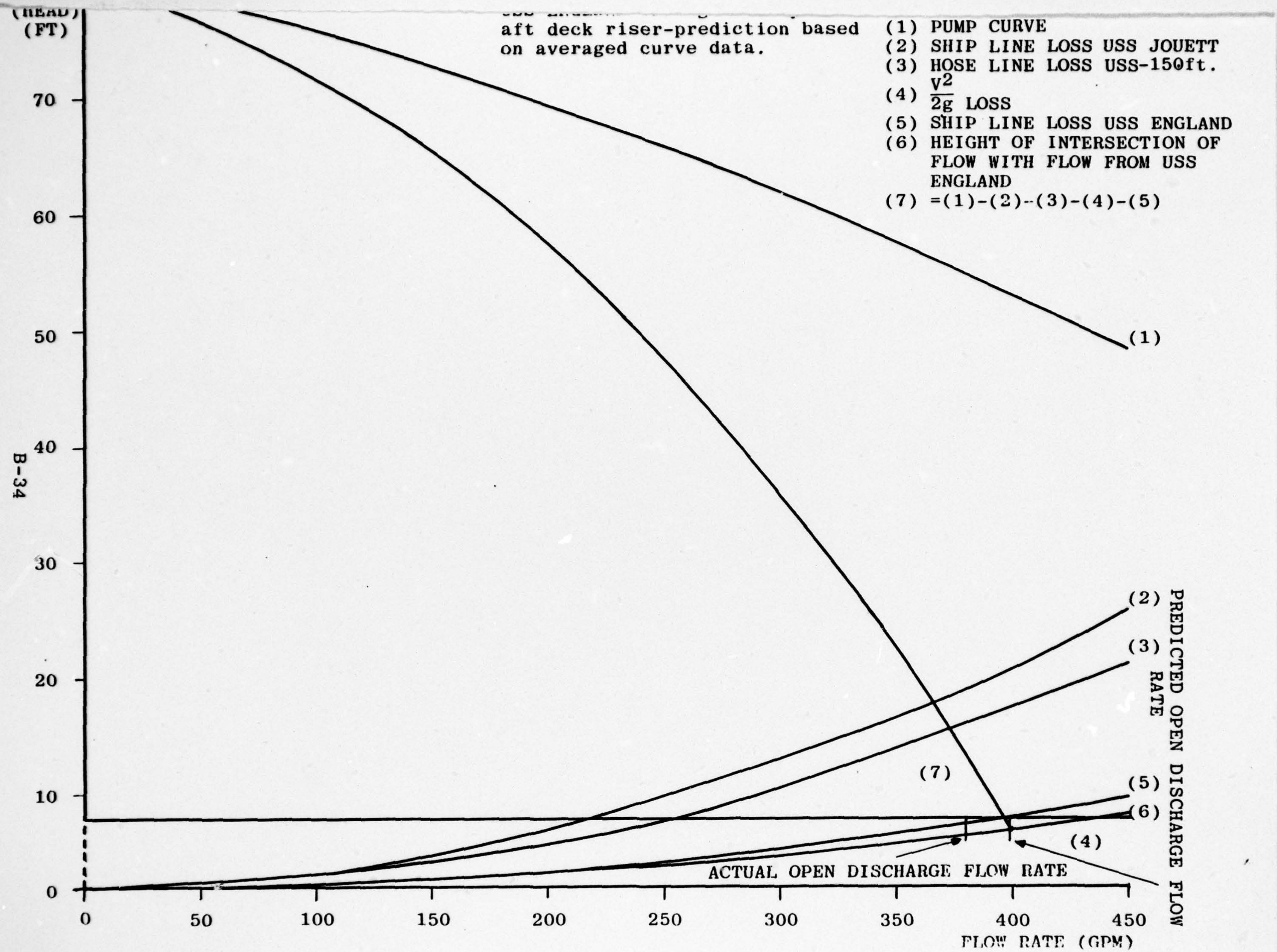
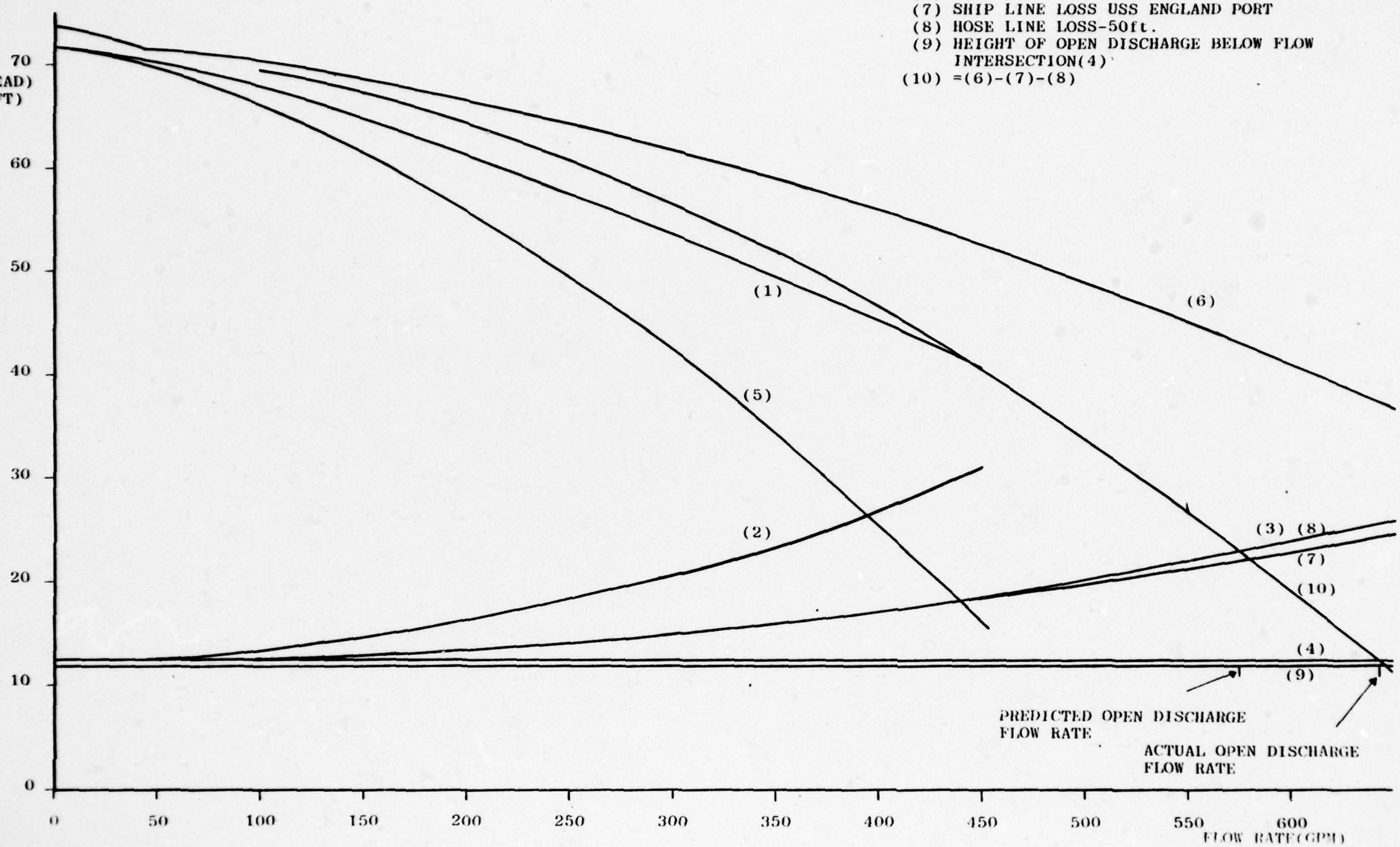

(HEAD)
(FT)
aft deck riser-prediction based
on averaged curve data.
(1) PUMP CURVE
(2) SHIP LINE LOSS USS JOUETT
(3) HOSE LINE LOSS USS-150ft.
(4) $\frac{V^2}{2g}$ LOSS
(5) SHIP LINE LOSS USS ENGLAND
(6) HEIGHT OF INTERSECTION OF FLOW WITH FLOW FROM USS ENGLAND
(7) =(1)-(2)-(3)-(4)-(5)
0
10
20
30
40
50
60
70
0
50
100
150
200
250
300
350
400
450
FLOW RATE (GPM)
(1)
(2)
(3)
(4)
(5)
(6)
(7)
PREDICTED OPEN DISCHARGE FLOW RATE
ACTUAL OPEN DISCHARGE FLOW RATE

FIGURE B-26 USS ENGLAND and USS JOUETT discharging combined flows through the USS ENGLAND port foward deck riser-prediction based on actual fitted curve data.

(1) PUMP CURVE
(2) SHIP LINE LOSS USS ENGLAND STBD
(3) $V^2/_{2g}$ LOSS
(4) HEIGHT OF INTERSECTION OF USS ENGLAND FLOW AND USS JOUETT FLOW
(5) =(1)-(2)-(3)
(6) =(5)+(7)-FROM FIG.B-22
(7) SHIP LINE LOSS USS ENGLAND PORT
(8) HOSE LINE LOSS-50ft.
(9) HEIGHT OF OPEN DISCHARGE BELOW FLOW INTERSECTION(4)
(10) =(6)-(7)-(8)



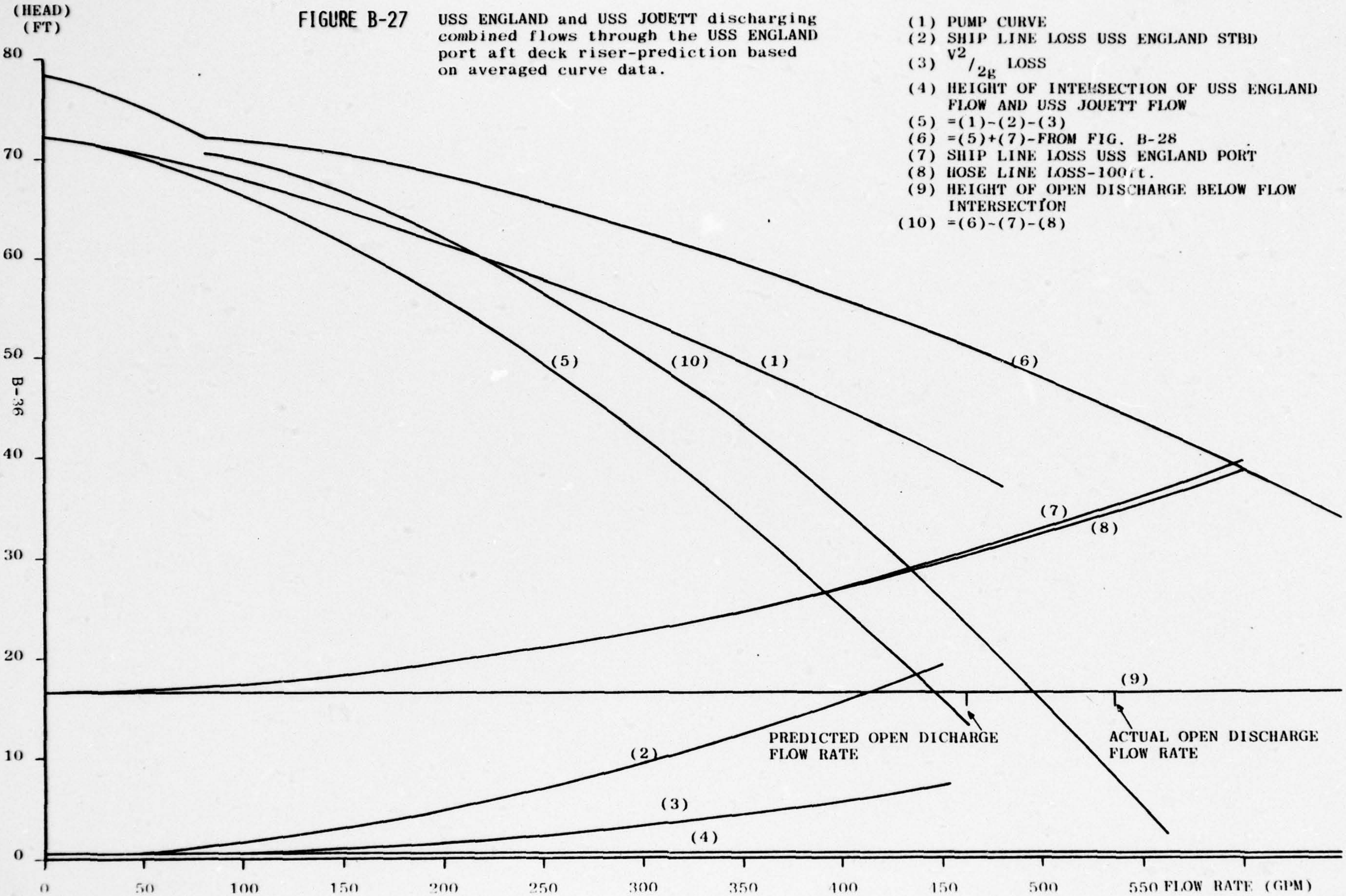


FIGURE B-27 USS ENGLAND and USS JOUETT discharging combined flows through the USS ENGLAND port aft deck riser-prediction based on averaged curve data.

FIGURE B-28 USS ENGLAND and USS JOUETT discharging combined flows through the USS ENGLAND port aft deck riser-prediction based on actual fitted curve data

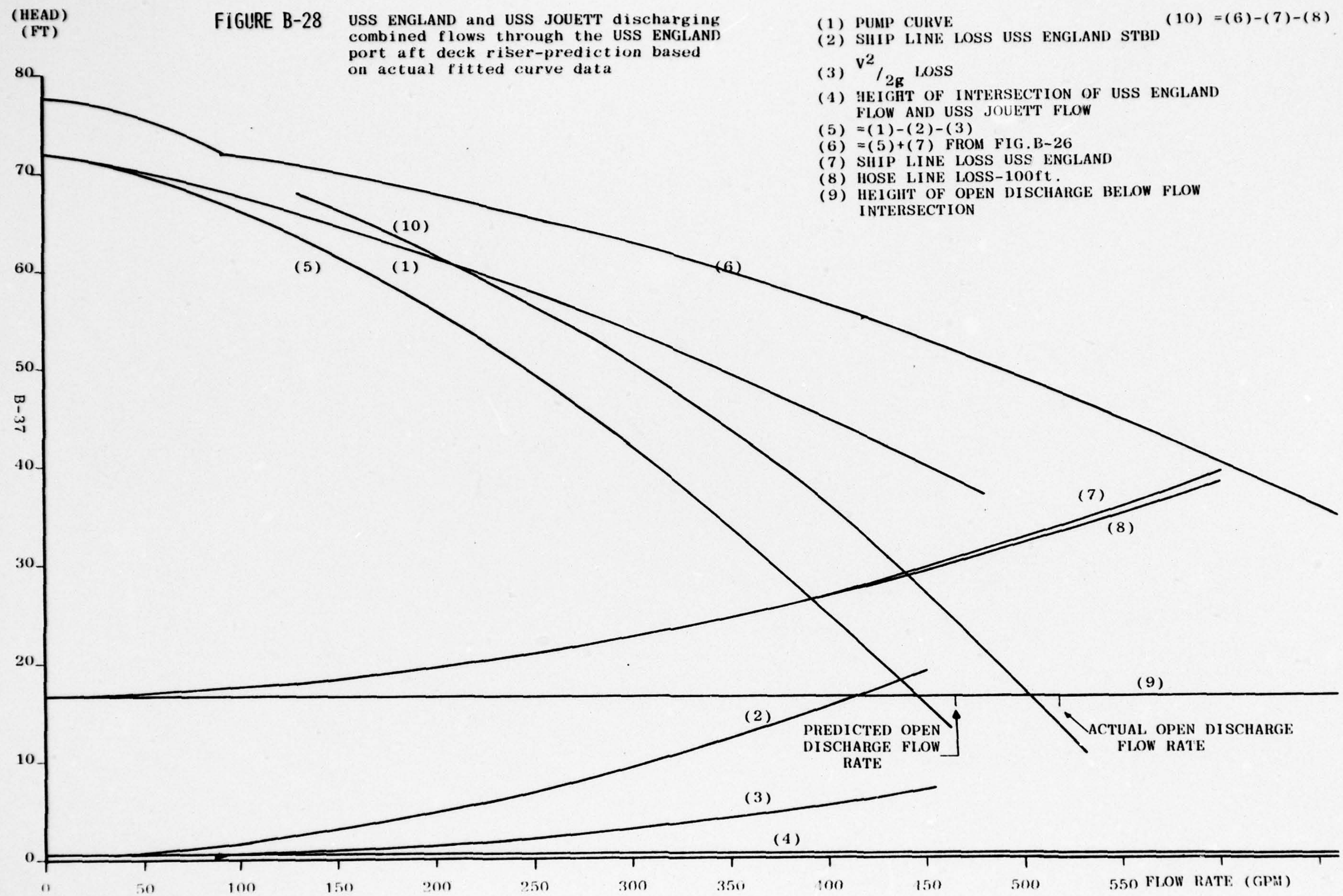


FIGURE B-29 USS ENGLAND and USS JOUETT discharging combined flows through the USS ENGLAND port foward deck riser-prediction based on averaged curve data.

(1) PUMP CURVE
(2) SHIP LINE LOSS USS ENGLAND STBD
(3) $V^2/_{2g}$ LOSS
(4) HEIGHT OF INTERSECTION OF USS ENGLAND FLOW AND USS JOUETT FLOW
(5) =(1)-(2)-(3)
(6) =(5)+(7)FROM FIG.B-24
(7) SHIP LINE LOSS USS ENGLAND
(8) HOSE LINE LOSS-50ft.
(9) HEIGHT OF OPEN DISCHARGE BELOW FLOW INTERSECTION
(10) =(6)-(7)-(8)